JANUARY 1958

THE WELDING JOURNAL

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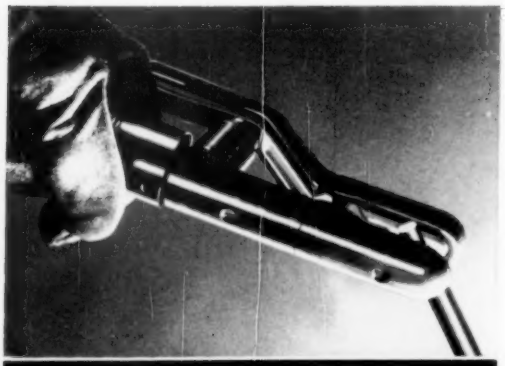
OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY

JACKSON for ARC WELDING



Insulated Copper Alloy Holders have greatest strength, hardness and conductivity. Jackson insulators have highest heat and impact resistance. Choose them where greater duty cycles are called for.

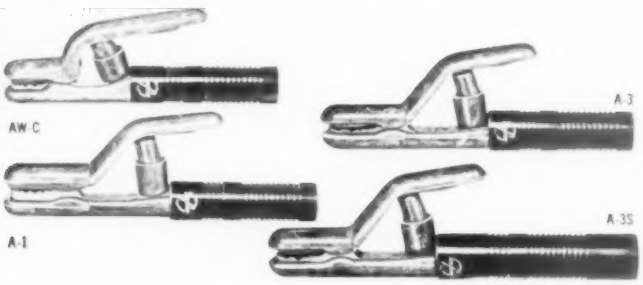
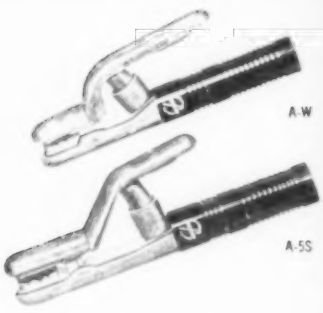
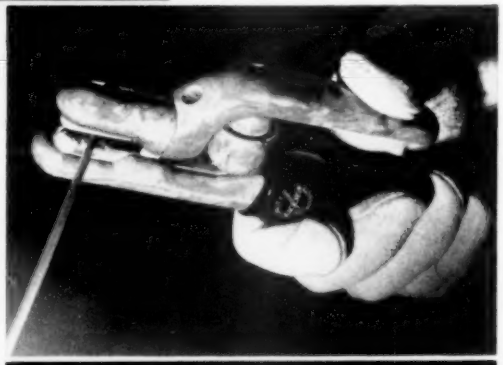


Table shows duty cycles possible with Jackson Insulated Copper Alloy Holders, using electrodes and cables shown.

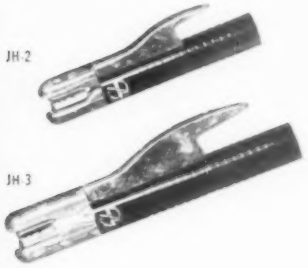
Holder Class	Model	Electrode	Amps & Cable	Amps & Cable	Duty Cycle
Small	AW-C	7/32"	250—No. 1	300—1/0	50%
Medium	A-1	1/4"	300—1/0	350—2/0	50%
Large	A-3	3/8"	375—2/0	450—3/0	65%
Heavy-Duty	A-3S	3/8"	500—4/0		80%



Featherlight medium class model A-W takes electrodes through 1/4" at 300 amps, weighs 14 oz. Featherlight larger model A-5S has wider tong and wider handle, takes electrodes through 5/16" at 400 amps.



Featherlight Holders have tongs of aluminum alloy, replaceable jaws of high-copper alloy. Excellent all-purpose holders, each within its rated capacity. Cable connection must be made mechanically.



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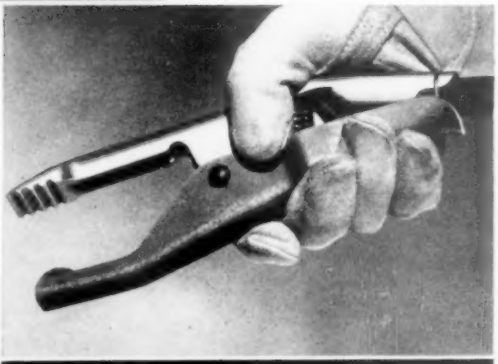
2/0—R* and 2/0	1/0 and 2/0	Mechanical, soldered, or brazed	500 amps
4/0—R* and 4/0	3/0 and 4/0	Soldered or brazed only	500 amps

*Cable Connectors only



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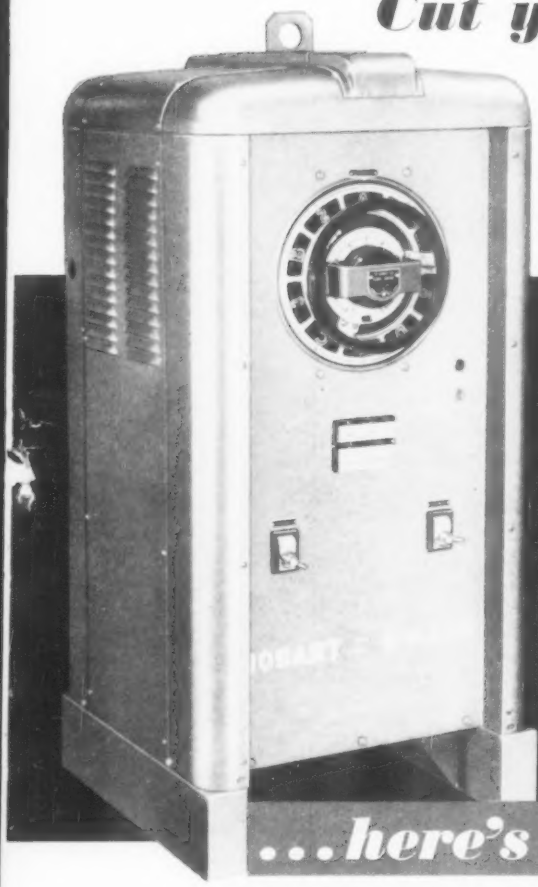

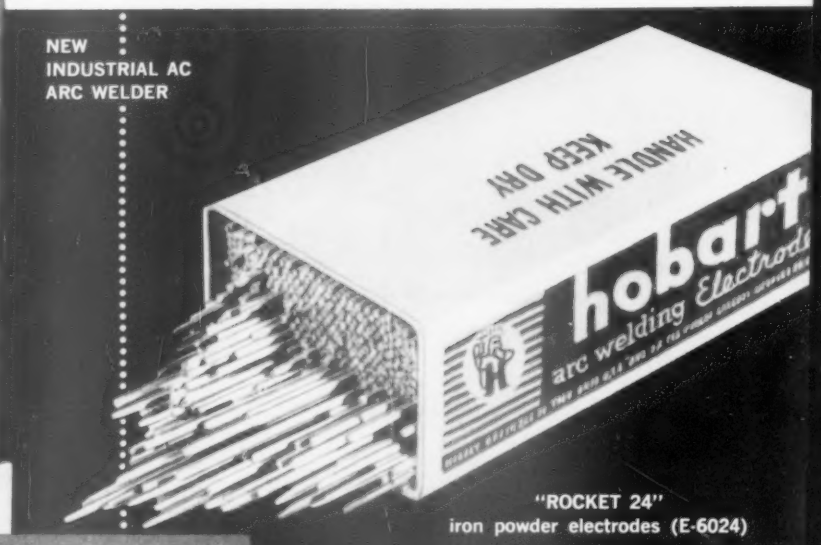

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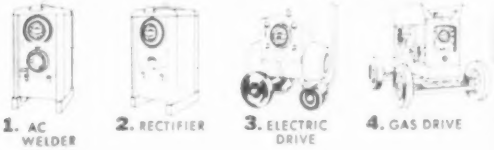

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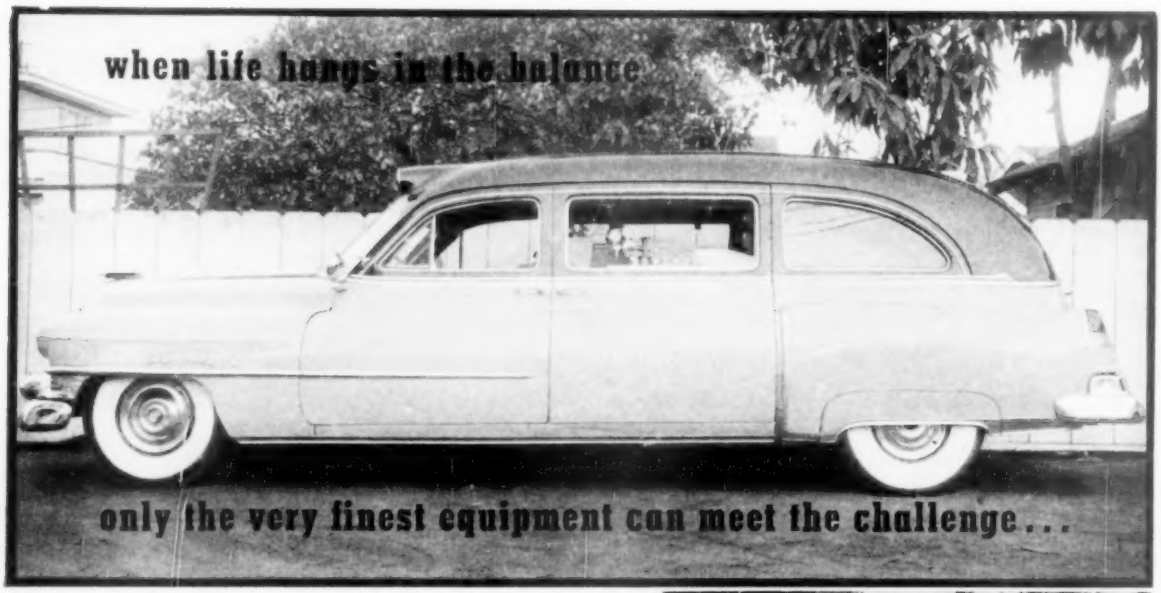

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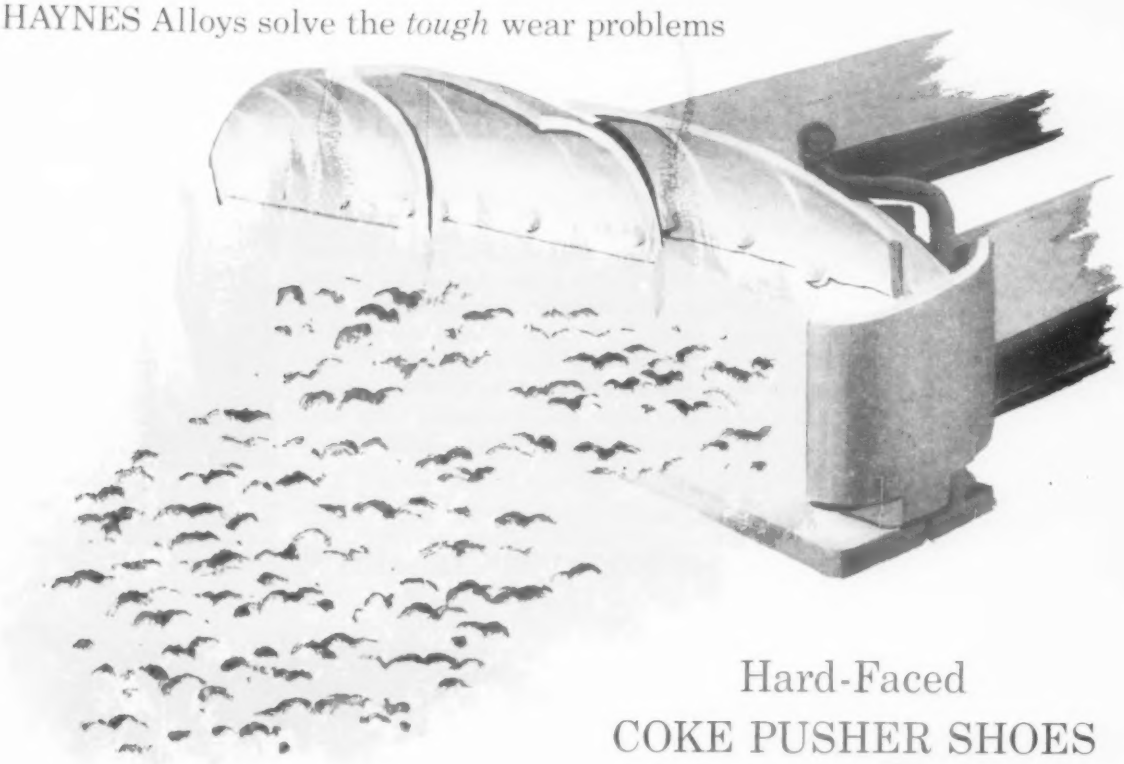

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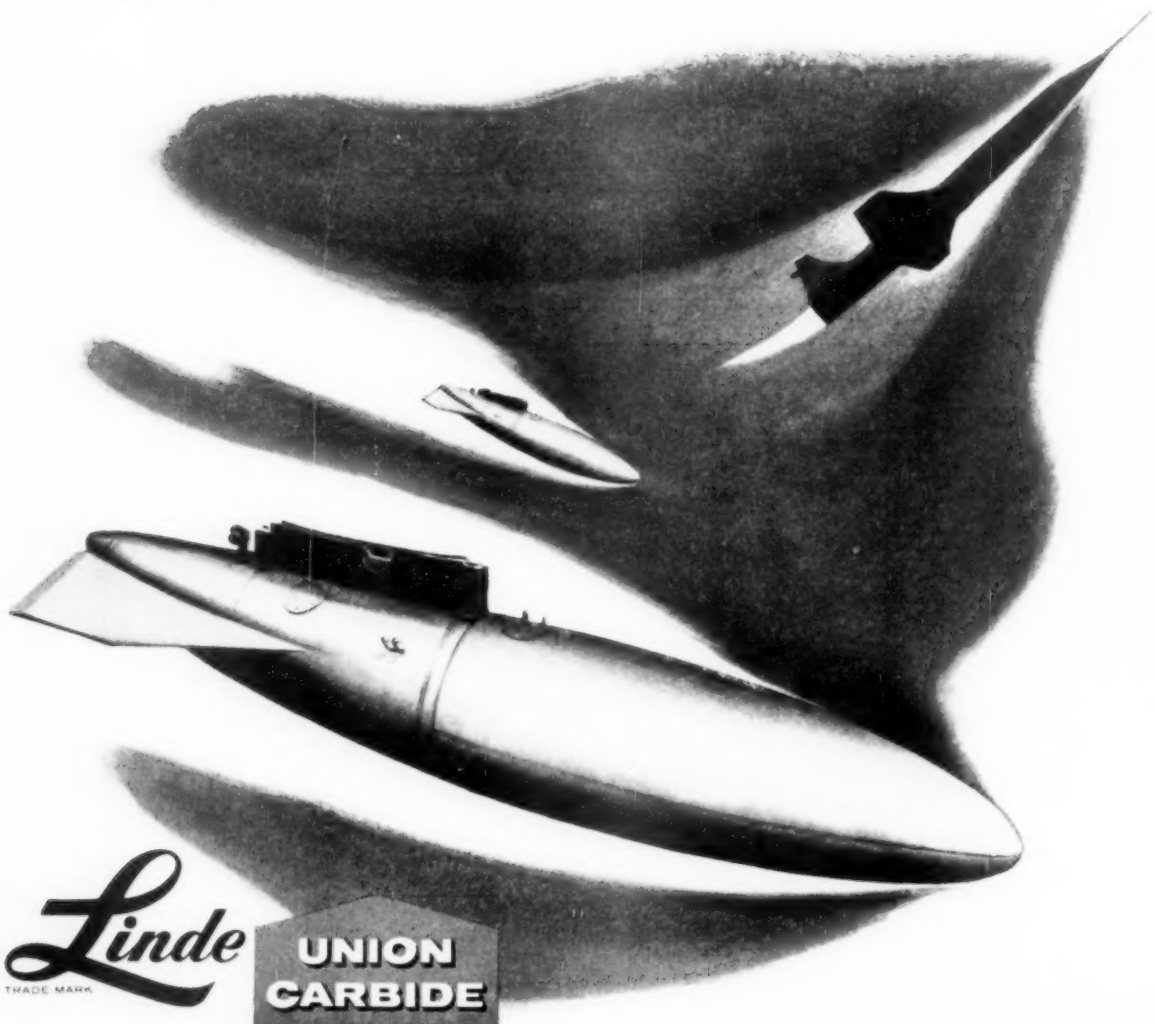

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THE WELDING JOURNAL

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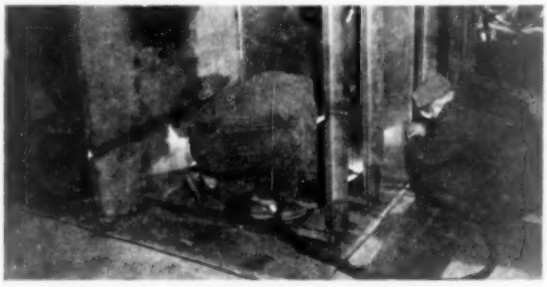
Inert gas and "60" Monel wire help Peterson[1] move full speed ahead on Monel tanks for Navy

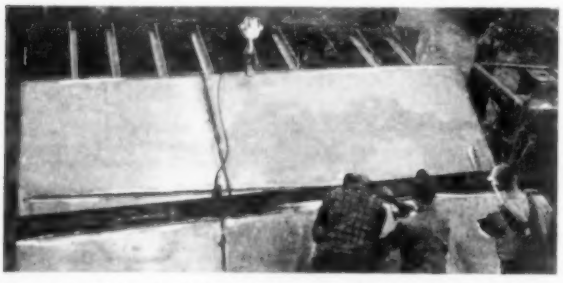
Peterson's layout men start by placing 5/32 inch and 1/4 inch Monel® nickel-copper alloy tank components on wooden patterns. During layout, plates are tack welded to prevent slippage.

After shearing, workers lightly grind edges to assure cleanliness . . . then reassemble and retack top plates as before, using the inert gas shielded tungsten arc method with 1/16 inch or 1/8 inch "60" Monel® wire.

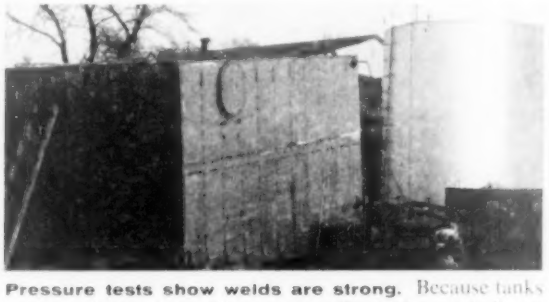
Weldors finish-weld top plates using 1/16 inch "60" Monel wire and Aircomatic® gun mounted on converted plate cutting machine. Then they tack frames to plate. Despite large number of welds, plates develop little warpage.



For rigidity of assembly to permit rotating tank for subsequent welding, swash plates go in next. With "60" Monel wire this operation moves fast. There's no need for flux or slag removal.



Crane rotates tank for position welding of side plates and finish-welding of frames. End plates, manhole flanges and piping are installed. Then the tank goes to testing.



Pressure tests show welds are strong. Because tanks are for minesweepers, Navy specs call for 10-pound oil test on fuel tanks and a 5-pound test on water tanks.

Inco's "SIXTY" series of filler wires are your best bet for predictable high quality welding of high nickel alloys.

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SAFETY—A CONTINUING CHALLENGE

Those who built welding to its present importance in American industry were aware, from the beginning, that safety is an important part of every industrial operation; also that acceptance of welding "safety-wise" by regulatory groups, industry and the public was essential to the unrestricted growth of welding.

Safety has a dual meaning in our industry—safety as it relates to the strength of welds, and safety as it relates to possible injury to persons and damage to property while welding.

The founders of our industry were faced with the problem of consistently producing welded joints that were at least as strong as the accepted riveted and bolted joints. They developed welding procedures, qualification tests for equipment, operators and welds; also design requirements. As a result, the mechanical strength of welds has now universally been accepted.

From infancy, our industry also has been fully aware of the potential fire and accident possibilities in the application of welding and allied processes. This awareness prompted AWS to sponsor the development of standards relating to fire prevention, accident prevention and health considerations. This awareness also caused other related societies and individuals to sponsor or develop similar safety work, work that will continue to receive the utmost attention.

In spite of past efforts, occasionally there still are welding accidents and fires, indicating that something is lacking—and there is. It is the education, training and supervision of the man that is usually involved in the accident—the man who handles the torch, electrode or machine. He is the one who can prevent most of the accidents. Thus, our number one problem today is getting the safety information contained in our standards and good practice manuals into the hands and minds of every welder and being sure that he understands and puts into practice basic safety and fire prevention fundamentals. This cannot be done by a few committees or individuals. It can only be accomplished through the cooperation and effort of every member of our industry.

Not to be safe is wasteful. To be safe is efficient, and it is good business to be efficient. Thus it behooves all of us to spread safety information to welding operators and their supervisors through education programs, instruction literature, pamphlets, advertising and any ingenious means at our disposal.

Safety is a continuing challenge.

H. F. Reinhard
CHAIRMAN
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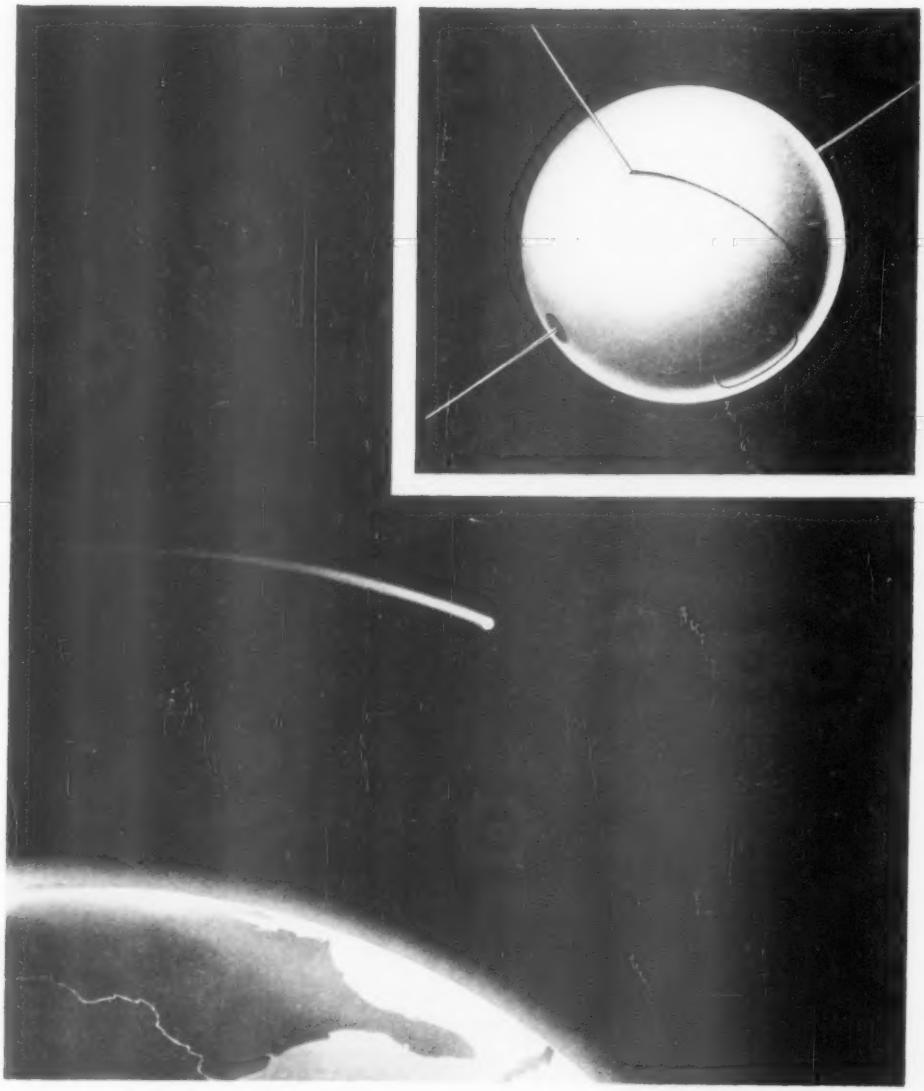


Fig. 1 Artist's conception of earth-circling satellite

THE DEVELOPMENT OF WELDING FOR ENGINEERING FABRICATION

Applicability of welding to all kinds of materials and thicknesses, for a wide range of service requirements, increases the flexibility afforded the design engineer

BY J. H. HUMBERSTONE

J. H. Humberstone is President of Air Reduction Sales Co., New York, N. Y.

Welding technology, as much as any other science, is making possible the physical exploration of our universe and space (Fig. 1).

Indeed, it is difficult to avoid the implication that welding is indispensable to our world. An examination of the facts forces us to the conclusion that welding is not simply the preferred process for fabrication but, in many vital instances, the only process.

Without going at any length into welding's many recent accomplishments in vital fields, let's touch on some of them—after reviewing briefly the growth of welding.

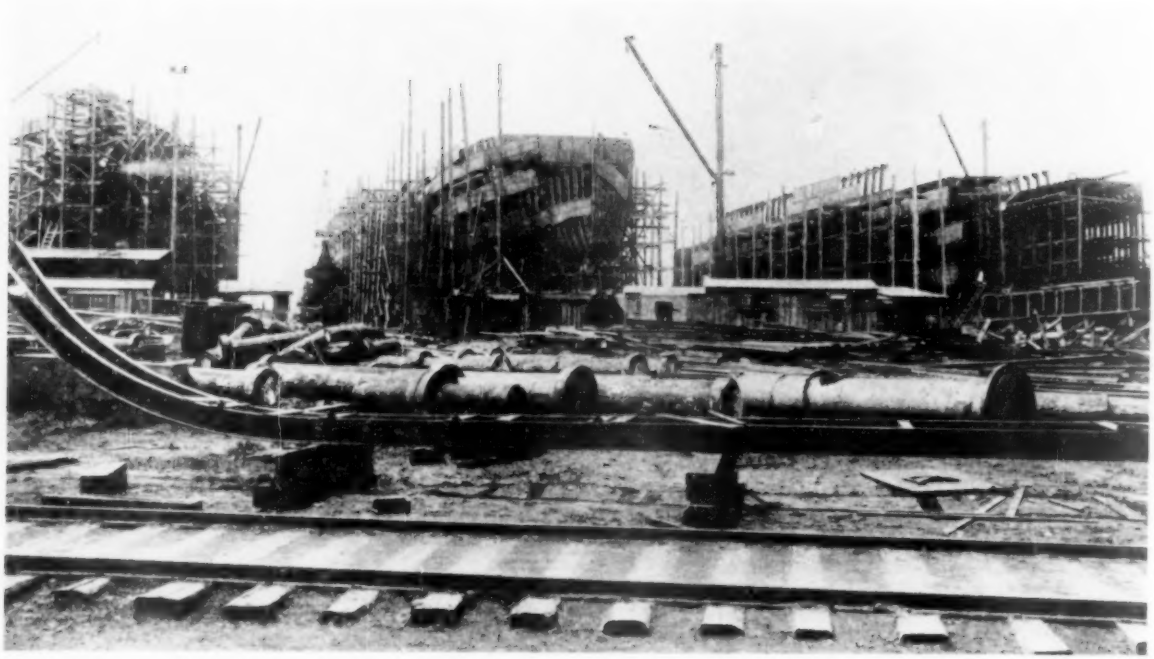


Fig. 2 Welding came into commercial use in the repair and conversion of ships (photo taken in 1919)

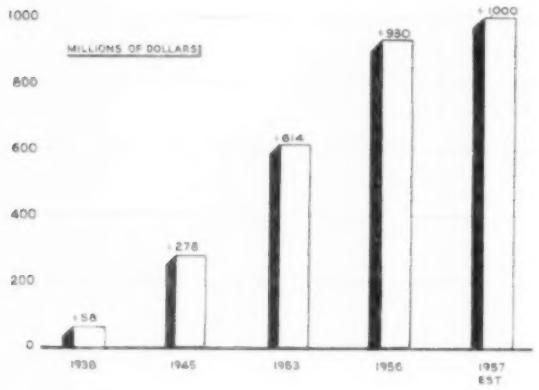


Fig. 3 Chart showing welding industry sales figures

Welding really came out of the blacksmith shop into commercial use during World War I in the repair and conversion of ships (Fig. 2). As we acquired more know-how in the shops, as research uncovered the basic principles, the use of welding grew in number of applications.

In World War II, welding was recognized as a vital factor in military production and in equipment maintenance at the fighting fronts.

Welding Comes of Age

Welding today is used in every metal-fabricating industry. It is used on every type of metal in commercial use. In fact, when a new metal is developed, one of the first things investigated to evaluate its commercial usability is "How can it be joined by welding?" Titanium and molybdenum are examples of this.

If welding did not exist, technical ingenuity would find a way to solve fabricating problems—even as we ask ourselves, "How are you going to hold 5000-lb. steam pressure at 1100° F without welding?" Out of necessity the answer would be found—but fortunately we don't have to look for it. We have the answer in welding.

Available to industry are 37 basic welding processes. These processes are in common use—performing many uncommon and spectacular jobs. But before we go into some of the specific accomplishments, let's take a look at a few figures.

Mounting Yearly Sales Figures

Last year, 1957, was the industry's best year with sales reaching about a billion dollars (Fig. 3).

This figure represents a picture of remarkable growth when placed against the background of a total welding industry sales figure of 58 million in 1938 — 278 million in 1945 — 613 million in 1953 — and 930 million in 1956.

That's the growth in dollars. Now, how about growth in skills? Without going into *which* welding process is used, or *how* the job is being done, let us examine a few examples of the progress made since the relatively crude work done in the old blacksmith shop.

Noteworthy Welding Performances

Stainless steel thinner than paper is being welded automatically. Material as thin as $^{3}/_{1000}$ in. is being production welded. It is possible to go as low as $^{2}/_{1000}$

in. One welding engineer put it this way, "We don't know how thin they're going, but we are going with them . . ." meaning, welding can and will meet whatever dimensional requirements industry demands.

In connection with light-gage welding, industry is now down to 15 amp on some jobs, and there are machines which permit welding to be done at $\frac{1}{2}$ amp. Contrast this with the 200 to 600 amp needed to weld thicker materials.

The welding of very thin sheet is a rapidly expanding field, and there are many welding processes available for the job. Electrical assemblies too small to be seen with the naked eye are being projection welded with the aid of optical magnification.

At the opposite end of the pole, strength requirements of 250,000 psi and higher are being met by welded joints on heat-treated high-tensile steels. Thicknesses of 8 to 10 in. are easily handled by welding to give joint properties and service performance equivalent to the base materials.

Speeds of more than 100 ipm are routine on $\frac{1}{4}$-in. thick aluminum. Steel tanks are seam welded at 600 ipm. Small diameter aluminum tubing is welded at the unprecedented speed of 800 ipm.

Titanium is welded in the same manner in which it is made; i.e., under a protective atmosphere of argon or helium, using the inert-gas-shielded processes.

There are instances where stainless-clad steel cannot be formed to satisfy the requirements of a particular assembly. The only recourse is to fabricate with steel and provide a stainless-steel surface afterwards. Welded stainless-steel overlays are high quality, economical and save on strategic materials.

Nuclear Power Developments

Important developments in the field of atomic energy, both today and in the future, would be impossible without welding (Fig. 4). In this field, nuclear reactors are designed to control as much energy as possible, as contrasted to atomic weapons designed to release maximum energy.

One of the critical problems in constructing fuel elements for one type of nuclear reactor involves the development of a welding procedure to *can* "slugs" of enriched uranium in zirconium "cases." The development of welding techniques to seal such cans or cases tightly has been a major accomplishment in the development of nuclear plants.

Another critical segment of a nuclear reactor is its piping. Because of the high temperatures and critical corrosion factors, zirconium and stainless steel are used for this piping. Much of the welding of this pipe uses the inert-gas-shielded tungsten-arc process.

One of the most intriguing fabrication problems that exists in the nuclear field involves the necessity for opening and then subsequently closing a container which is contaminated either as a result of its service or because of "hot" materials contained therein. The special, remotely controlled servo systems required for rewelding or assembling components of this type have presented requirements which involve complex elements of almost every known technology. It has been a tribute to the maturity of the welding engineer that he has been placed in a position of trust with respect to the solution of this extremely important problem.

The Trend Toward Mechanization

In every field, not just atomic energy, new designs to meet unprecedented requirements demand more efficient fabrication on a *production* basis (Fig. 5). Mechanization of welding processes has become necessary, not merely for high production and reduced costs per unit of output, but for *quality*. Quality requirements are so exacting on some projects that they make machine welding mandatory, the machine completely replacing the human element.

Consider the demanding dimensional tolerances imposed in aircraft gas turbines or jet engines; in a 36-in. diam engine the rotor blades have the almost unbelievable small clearance of $\frac{2}{1000}$ to $\frac{3}{1000}$ in. These blades move at supersonic speeds and at temperatures approaching 2000° F. And the remarkable fact is

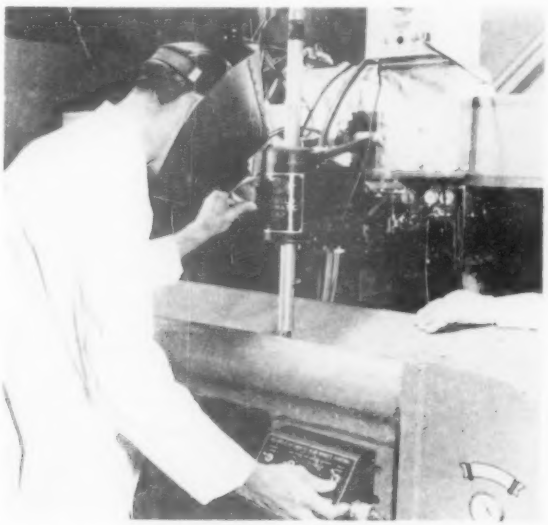


Fig. 4 Sheet-metal units for nuclear-power reactor being joined by inert-gas-shielded tungsten-arc process

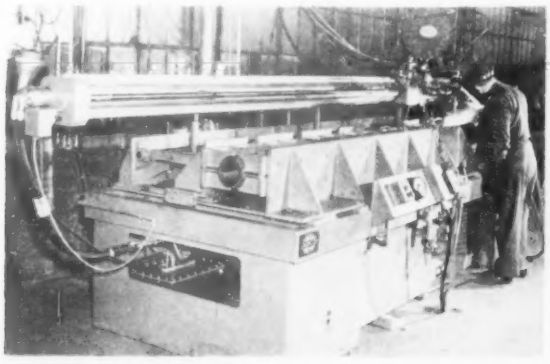


Fig. 5 Mechanization of welding processes has become necessary for quality as well as high production results

Fig. 6 Jet bombers such as the one shown above require many welding processes for their construction

Fig. 7 Rocketry and missile developments are opening new markets for welding products and processes

that, to describe this requirement, is to describe the accomplishment of machine welding in this field, a feat which would have been considered "impossible" by welding authorities a few short years ago.

Meeting Aircraft Requirements

The ability of welding processes to meet the requirements imposed by supersonic, high-temperature service conditions in a wide variety of metals is now universally recognized in the aircraft industry (Fig. 6). Many assemblies require the use of high-temperature filler material for their fabrication. Brazing techniques — manual, automatic, dip, furnace — are extensively used. Sheet components are spot, seam and projection welded. Flash welding is used for engine mounts, nacelle spar assemblies and similar aircraft components (Fig. 7).

As the aviation industry advances, weight penalty is becoming more important. Mechanized welding is proving to be the only way to fabricate many components — such as "sandwich" panels which are being designed to meet modern aerodynamic requirements. Its role in aviation is expected to expand extensively.

The Age of Steel Aircraft

Material requirements for supersonic flight have already ushered in the age of the steel aircraft. The stresses, high temperatures and other environmental factors associated with supersonic flight, plus the weight penalty factor indicated above, in many cases have dictated the use of precipitation-hardening stainless steel for construction.

Aerodynamic considerations involving frictional heating effects have made welding the only practical fabricating procedure for such aircraft. The reliability of welded fabrication for this type of service is no longer a subject for engineering debate.

The Automotive Industry

Getting down to earth again, welding in the automo-

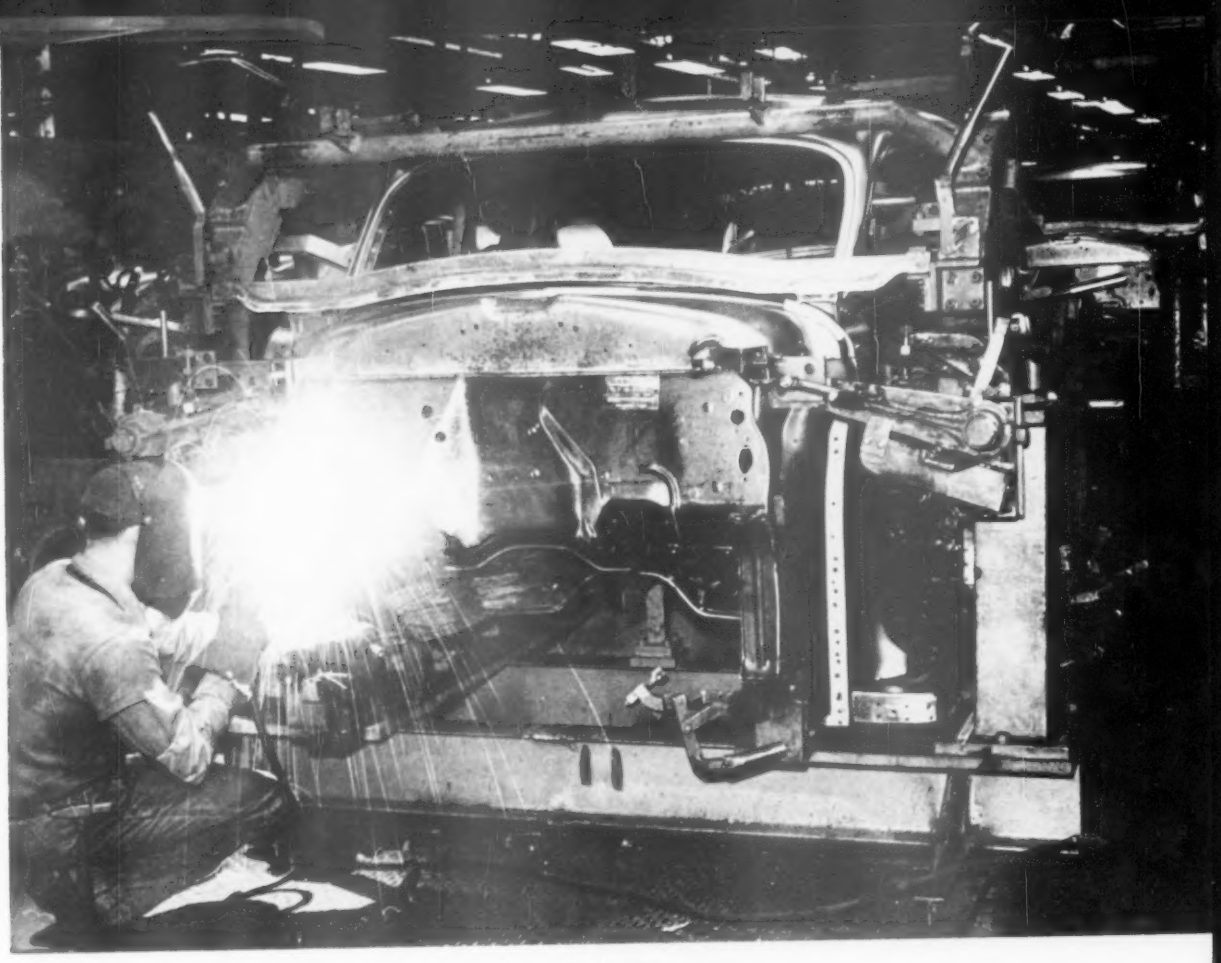


Fig. 8 An arc welder reinforcing the body of a car during the framing process

tive field presents an interesting picture. There are about 8000 welds of the resistance type in a passenger car body. By multiple spot welding, as many as 100 welds can be made simultaneously in one part, and 300 parts can be welded in 1 hr. . . . A typical car frame has from 300 to 500 in. of arc welding (Fig. 8). . . . Steel gasoline tanks are seam welded at a rate of 600 ipm. . . . Automobile engine blocks are cast in large numbers, and all defects—large and small—are removed by welding. Salvaging of these castings has become a routine production job for welding.

From a purely economic standpoint, it has been widely acknowledged that, *without welding*, the expense of producing a car would be much higher. Automotive companies which supply parts to the automotive manufacturers are going all-out on mechanized welding processes to volume-produce steel parts. Many are using CO_2 as the shielding gas for automatic applications of the gas-shielded metal-arc process.

The story is much the same in the truck field. At one large company each platform trailer requires approximately 300 ft of welding consisting of more than 500 welds on various joints, most of them 4 in. long. Both production speed and high quality results are obtained by application of the gas-shielded metal-arc process.

Economies of Welded Construction

Welded structures save steel required for connections and make possible, through design methods, savings in beam and girder tonnages as high as 40%. Studies indicate that if 80% of our structures were weld fastened, we could expect a yearly saving of at least a quarter of a million tons of rolled-steel shapes. Of fifteen hundred structures designed for welded fastening of the structural frames, not one failed to save more than 10% of the steel required by other methods of assembly.

There is another important advantage: faster erection. This is related to the simplicity and speed of welding and also to the fact that much work can be prefabricated in the shop instead of on the job.

For similar reasons, almost all highway bridges of girder construction are now totally or partially welded. In fact, when federal aid is requested for a highway bridge, the U. S. Bureau of Public Roads requires all designs to meet the American Welding Society's specifications. . . . Low-hydrogen electrodes and low-hydrogen iron-powder types are offering faster production of lighter-weight bridges. It has taken time, but the economies of welded construction are overpowering the resistance based on the inertia that surrounds past practices.

Pressure Vessels and Piping

In the power field, welding has made possible the use of high operating temperatures and pressures. Boilers and pressure vessels, large and small, are 100% welded (Fig. 9). The same is true of water and oil storage tanks. A related aspect of this is the vast network of welded transmission lines spanning the U. S. today. Welded pipe lines range from diameters of 6 in. to more than 30 ft—as at Hoover Dam. These lines carry water, oil, gasoline and natural gas over long distances and through remote and desolate regions where defects and breaks are costly. Similar lines distribute chemicals, syrups and other fluids over short distances or within a single plant.

Advantages to the Railroads

In the railroad industry, weight reduction in low-alloy high-strength steel cars is being accomplished by welding, eliminating rivets and designs for rivets. A strong current trend in the railroad industry is the use of tungsten-arc spot welding for fabrication of stainless-steel panels and side sheathing on passenger cars (Fig. 10). This process is also used in food storage, dispensing and refrigerating equipment.

Welding's repair function alone means a tremendous reduction in costs of replacement parts. And this applies to all branches of industry. Quite apart from its emergence as a primary fabricating tool, welding has become economically indispensable to industry as a repair and maintenance tool.

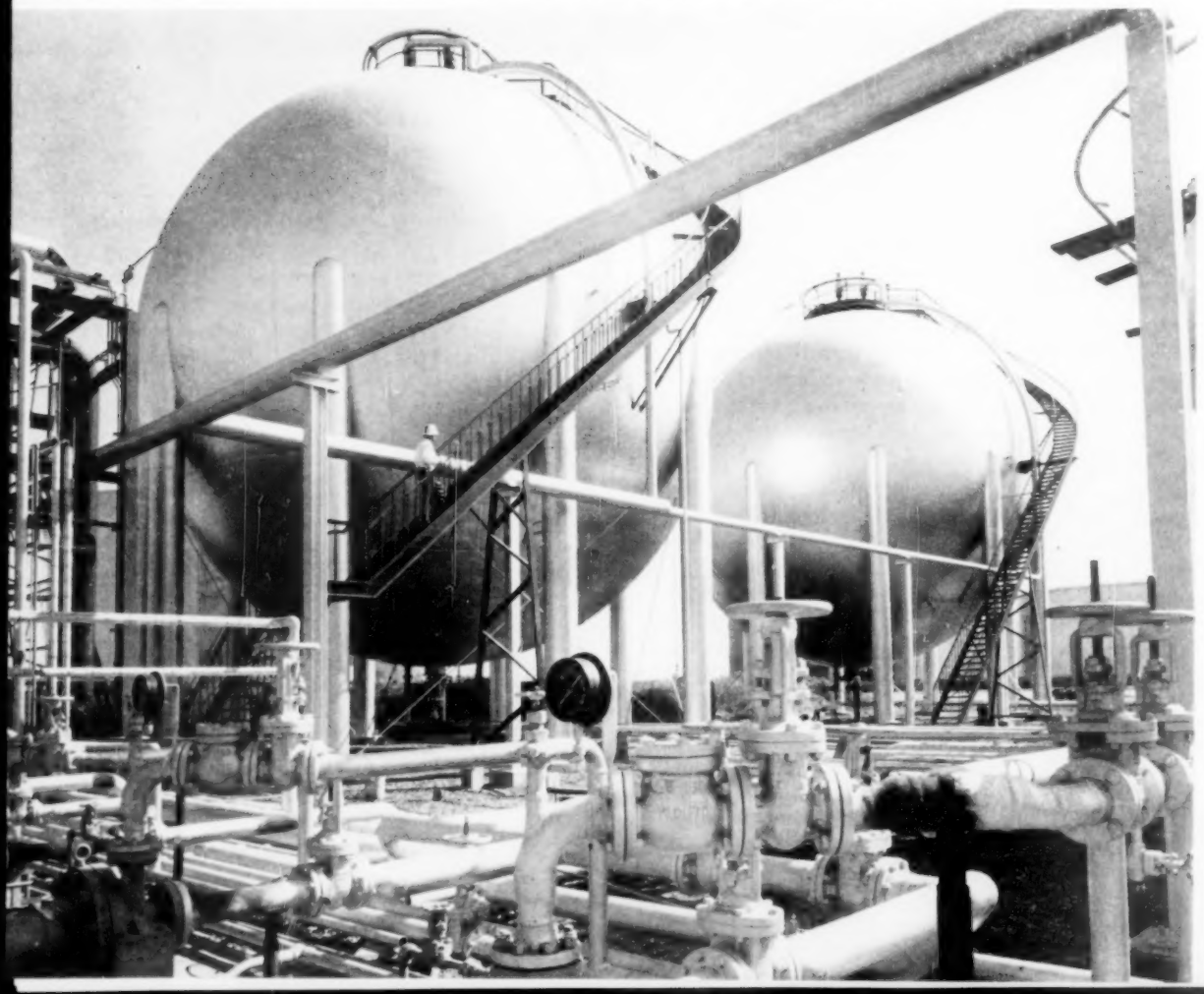
Revolution in Shipbuilding

Perhaps the most dramatic change in the role of welding has taken place in shipbuilding. From its simple, but important, repair function in World War I, welding has advanced until today it is a primary method of fabrication. Because of welding, hull weights have been reduced 5 to 10%, and maintenance costs have been cut about 25%. It has made possible the prefabrication of sub-assemblies, an important factor in shipbuilding economies because it shortens the time required on the ways and in drydock. Besides these direct benefits, there are side benefits when welding assumes a major role. In shipbuilding, it has been possible for shipyards to convert to other fabrication in slack periods. This promotes greater employment stability and means that the shipyards and their skilled labor forces will be available when needed in national emergencies.

Aluminum Superstructures

While on the subject of national defense, the Navy has been able to design considerable amounts of aluminum into its new warships, due primarily to the revolutionary performances of the inert-gas-shielded weld-

Fig. 9 Storage tanks and piping systems are extensively weld-fabricated at modern oil refineries



ing processes on that material (Fig. 11). Some of the new aircraft carriers use about four million pounds of aluminum and new destroyers use about 200,000 lb.

In considering the over-all use of welding in warship construction, it is interesting to note that in building the U. S. S. Forrestal about two million pounds of weld metal were used, and there were 2400 miles of [illegible]-in. welding on both steel and aluminum.

Flexibility for the Design Engineer

In general, then, from the foregoing facts, it is easy to see that the applicability of welding to all kinds of materials and thicknesses, for a wide range of service requirements, has actually increased the flexibility afforded the *design* engineer. The welding engineer—the design engineer—can now *design for function*. It is no longer necessary to restrict *the way* in which a particular form or shape can be achieved to the stereotyped designs established for older fastening methods. This great contribution is an accomplishment in which the entire welding industry can take justifiable pride.

However, when progress is rapid, as it has been in welding—particularly in the last ten years—there is an inevitable lag between new needs and the development of new methods to meet them.

For industry to reap maximum benefits from welded fabrication, it is essential that it have a thorough background in—and appreciation of—welding; not only the practice but the *technology* of welding must be properly evaluated, promoted and made readily available to engineers—in fact, to all who have anything to do with fabrication.

The Role of the Welding Engineer

It is important in this connection to keep in mind that the welding engineer provides the coordinating link between the activity embracing materials, design and methods of fabrication. Consequently, it is necessary that these men be exceptionally well trained in each of these three large areas. No other field of engineering involves the breadth of technology demanded in this area of specialization.

Basically, our approach to current and future problems must be *educational*. It is glaringly evident that welding's role in industry is not adequately reflected in the current training programs of our engineering schools and universities. Only a few schools offer more than a brief, superficial exposure to welding. Less than a handful actually give degrees in welding engineering, a profession which has earned the stature and dignity of a major degree rating. Only a smattering of welding courses are offered at the graduate level. Yet, the entire future of welding depends on the directed energy of competently trained engineering students. All engineers, student and professional, regardless of their specialization, need now more than ever before a thorough background in the technology of welding.

Moving Toward Full Recognition

The lag between what is happening in industry and what is being taught in the classroom will, no doubt, be corrected. Certainly the welding industry, now alert to this problem, will exert its efforts toward the obvious solution.

The educational process does not end with formal training in schools. It is a process which goes on continually and is part of the responsibility of those in industry. . . . Users of welding should inaugurate and encourage in-plant training—training for the shop crew and *an appreciation* of welding on the part of the entire organization.

These are some of the approaches which will bring us closer to a full recognition and capitalization of the vital role that welding is playing and will play in our industrial future.

Fig. 10 Tungsten-arc spot welding is used for fabrication of stainless panels on railroad passenger cars

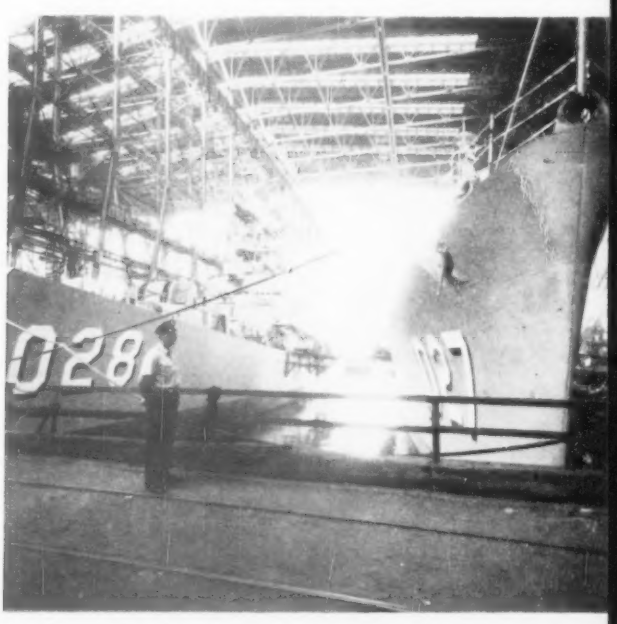


Fig. 11 Navy destroyers have all-aluminum superstructures welded by the inert-gas-shielded metal-arc process

NEW TECHNIQUES IN PRECISION-WELDING CONTROL

An electronic control which has been applied to the control of the many functions required in the resistance-welding process is described by the authors

BY J. L. SOLOMON AND M. BALIKOV

INTRODUCTION. In May 1956, a paper* was presented which described a new concept in resistance-welding control. That concept was the control of function duration by counting cycles rather than timing by the use of resistance-capacity circuits.

It is the purpose of this paper to describe the physical realization of that concept and some of our experiences over the past years in developing this new system.

Development of Control System

Four basic considerations guided the development of the control system:

1. That the control be extremely reliable and absolutely accurate in its timing and operational functions.

2. That it be designed for the most efficient utilization of its components.

3. That the control provide types of functions, function duration and relation with other functions for the most flexible and effective performance of the welding operation.

4. That the control be free from all adjusting devices such as are commonly used with resistance-capacity type of timing circuits in order to compensate for variations and changes in the value of components due to aging and environmental conditions.

From the beginning of the resistance welding art, progress was made in the welding technique as more accuracy in the control functions was realized. In the beginning, devices utilized for the timing of welding current were mechanical in nature, and as we progressed in our knowledge of electronics, electrical and electronic timing devices and current control devices were utilized. Generally, the timing control devices utilized to date have been through combinations of either vacuum or

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Paper presented at the AIEE Electric Welding Conference held in conjunction with the 1957 AWS National Spring Meeting, Philadelphia, Pa., April 8-12.

* Farrell, W. J., and Solomon, J. L., THE WELDING JOURNAL, 36 (4), 356 (1957).

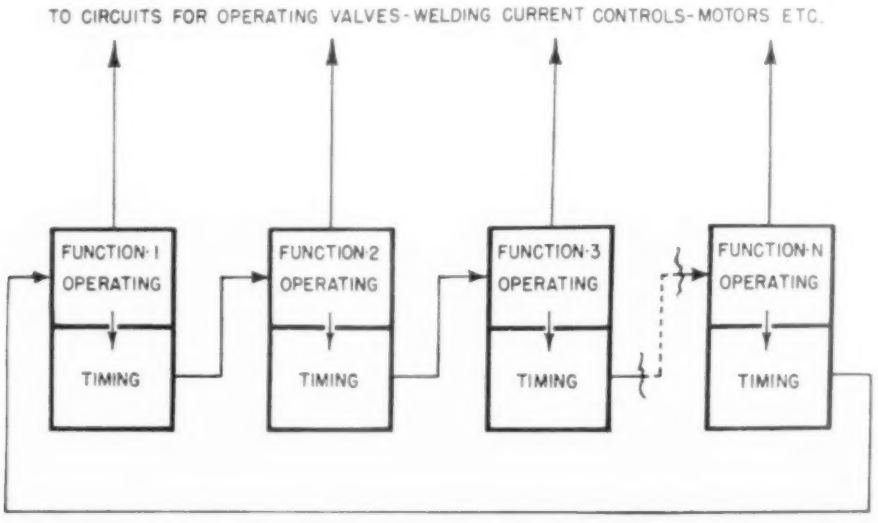

Fig. 1 Electronic control using RC timing circuits

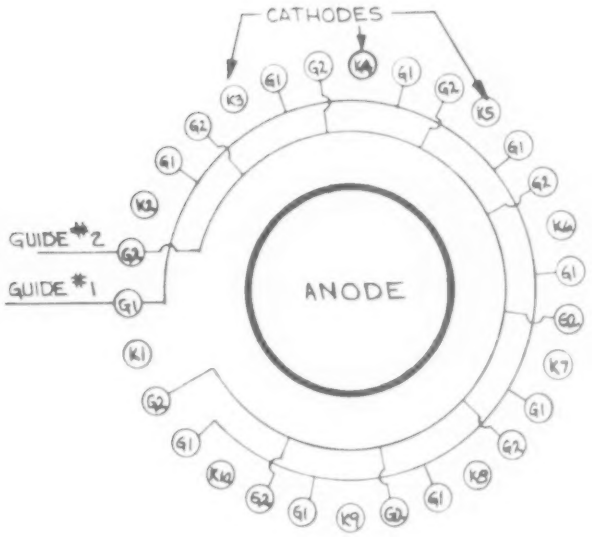

Fig. 2 Arrangement of Dekatron cathodes

gas tubes associated with resistance and capacity timing networks. Complete systems were developed using individual timers operating relays which were initiated in sequence in accordance with the functional requirements of a particular machine. In recent years, fully-electronic circuitry was developed which eliminated to a great extent the use of relays.

Figure 1 is a block diagram of a control of this period in which RC timing circuits were utilized for timing those functions which were indicated in cycles, and cold cathode pulse counters using one tube per count were used for counting welding impulses.

At about the time these units were developed, a reliable cold cathode glow transfer tube† having a multiplicity of cathodes was developed which held the promise of providing a practical means for realizing a control based upon the counting concept.

† Bacon, R. C., and Pollard, J. R., *Elec. Eng.*, **22**, 172 (1950).

The Dekatron tube is constructed with a common anode and a multiplicity of cathodes. One type of tube is produced with 10 individual cathodes which are brought out of the glass envelope for external connection (Fig. 2). Between each cathode are placed two additional cathode elements called guides—guide 1 and guide 2. All of the guide 1 elements are internally connected together, and all of the guide 2 elements are internally connected together with the common connections for each group available externally. Let us suppose that the tube is connected as per Fig. 3. With the application of a suitable potential, approximately 400 volts, between anode and the common cathode connection, one of the cathodes will become conductive. In the quiescent state the guide elements are maintained at a positive potential above that of the cathode. If we introduce a negative pulse to the common guide 1 terminal, the glow will transfer from the cathode which is glowing to the adjacent guide 1 element. If, as the pulse is being removed from guide 1, we then apply a second pulse to the guide 2 terminal, the glow will transfer from the guide 1 element to the adjacent guide 2 element. When the pulse is removed from guide 2, the glow will then transfer from guide 2 to the closest cathode, inasmuch as the guides are maintained more positive than the cathodes. In this way by the application of successive impulses to guide 1 and guide 2, the glow may be transferred from cathode to cathode within the tube. A voltage is developed across the resistor in the cathode circuit of a particular cathode during the time when it is passing current. This voltage may be used in conjunction with an amplifier to deliver a signal for purposes of machine control.

The first approach in utilizing this tube is shown in the block diagram of Fig. 4. Each function contains an input circuit to the unit Dekatron; a transfer circuit to the decade Dekatron; an output circuit; and a resetting system for preparing the Dekatron count for the next operation. In addition, a pulse source and a pulse distribution or gating circuit are required in order to deliver pulses of the proper type to each stage.

This type of control was designed for use in seam and

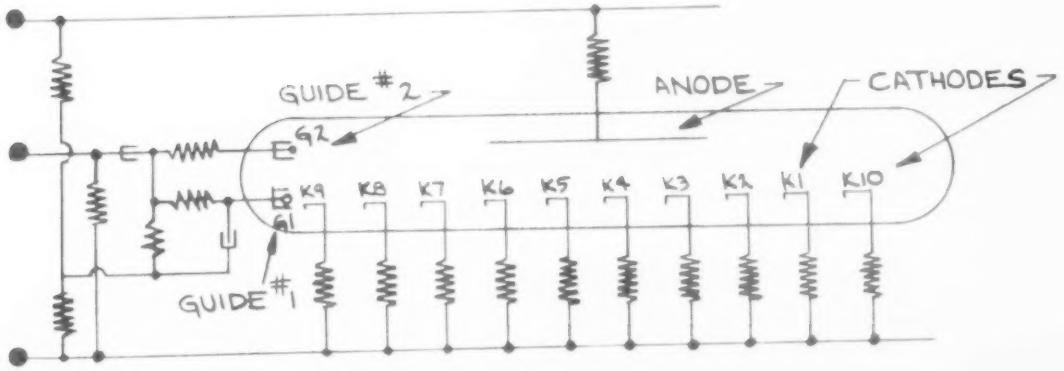

Fig. 3 Schematic of Dekatron circuit

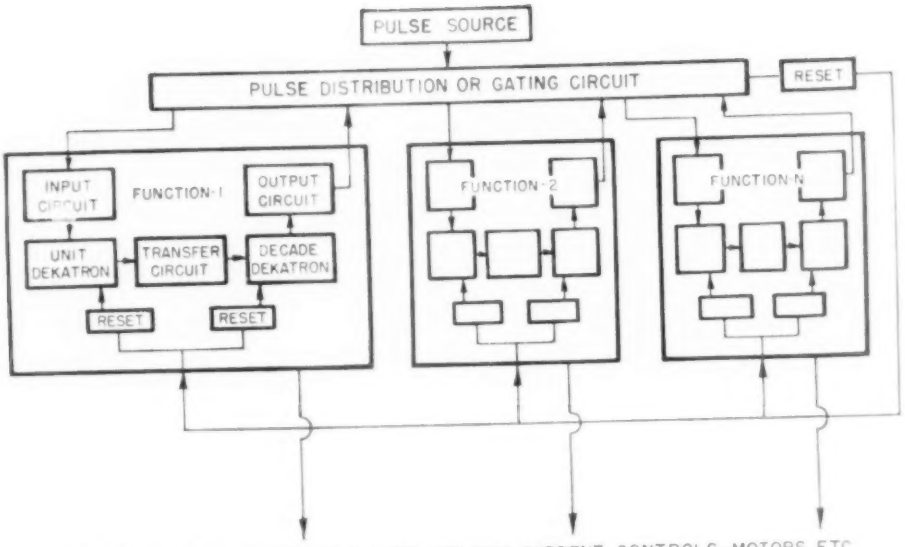

Fig. 4 Dekatron control using individual Dekatrons for each function

spot welders using a limited number of functions. The next problem, after developing a number of controls using this approach, was a control for spot and seam welders used by the aircraft industry. It became apparent that a reduction in the number of elements would be desirable inasmuch as a control for a seam welder of this type could require as many as nine sequential timing functions, also *cool-heat* timers for *preheat*, a second for *weld*, and a third for *postheat*. Thus, if separate Dekatron circuits were used for each function, 27 Dekatron tubes with 9 associated input, reset and output circuits would be required based on a count of 100 cycles or pulses for each sequential function, and a count of 10 cycles for each *heat* and *cool* function. Each block would be repeated 9 times, or as many times as functions were required.

In order to reduce the number of Dekatron tubes and associated tubes required, the system shown in Fig. 5 was developed. In this system, one of the counting blocks shown in Fig. 4 is used over and over again to count either pulses at line frequency rate or at welding current impulse rate. This system functions as follows: pulses are delivered to the Dekatron until the preset count is reached which then delivers an output pulse to the function stepping circuit, switching it to the next stage. A reset pulse is delivered to the Dekatrons to preset them to the desired number of pulses for the second function. If this is a welding function, pulses are delivered to the Dekatrons at the end of each welding impulse until the preset number of pulses has been delivered. At this point an output pulse is again delivered to the function stepping circuit which switches

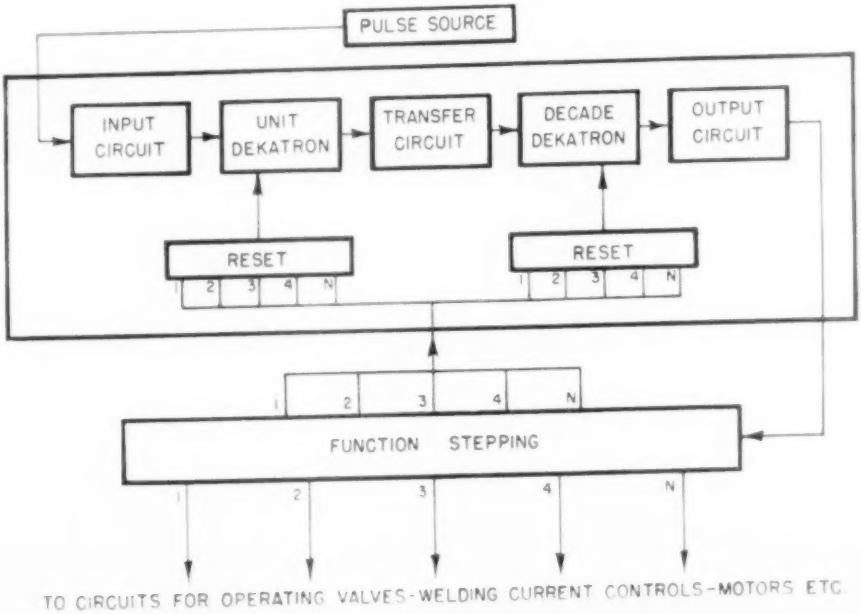

Fig. 5 Dekatron control using one Dekatron circuit for all functions

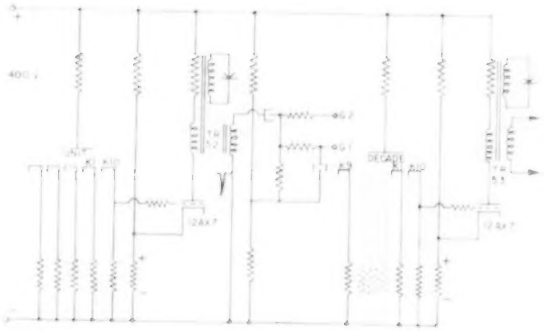

Fig. 6 Dekatron counting circuit

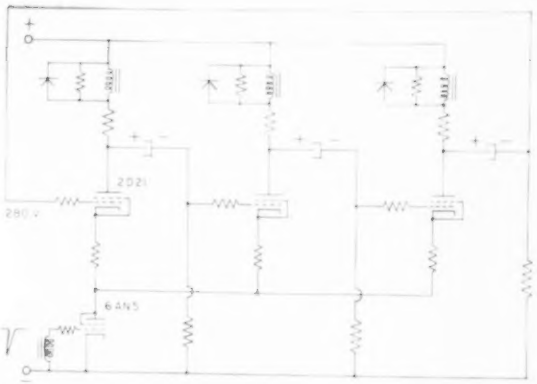

Fig. 7 Function-stepping circuit

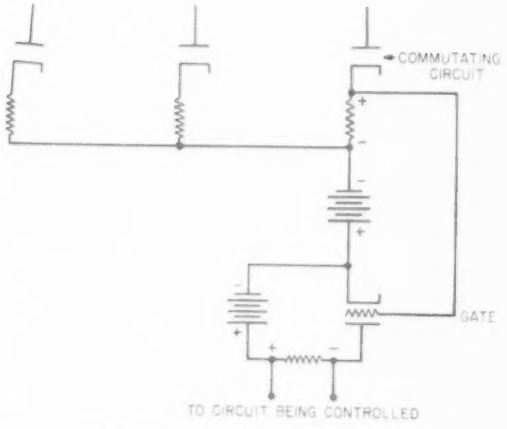

Fig. 8 Gating circuit

to the next stage. The Dekatrons are preset for the desired number of pulses and the count for the third function begins. In this manner, any number of functions may be timed, reusing the same set of Dekatron tubes for each individual count.

The first form of a function stepping circuit was one utilizing a relay stepping chain in which the relays were energized in succession as each pulse was delivered to the function stepping chain. A complete control of this type was connected to a three-phase spot welder and exhaustive tests conducted to check the over-all operation of the system. As a result of these tests, it was decided to replace the relay stepping sequence with a fully-electronic function stepping circuit. This last control was put through many millions of operations and found to be extremely reliable.

In our basic considerations for the control we had imposed the provision that the control be free from all adjusting devices. In order to satisfy this provision, calculations were made to determine the range over which each component could be varied in size and still allow proper functioning of the control. Each component was selected to fall at the center of the allowable range and it was found that components of normal 5% and 10% tolerance, which are readily available, could be safely used in all circuits and still allow correct operation over a change in line voltage of plus or minus 12½%; a range which is greater than that which can be tolerated by thyratrons.

We were also very much interested in determining whether the Dekatron tubes would be sensitive to strong magnetic fields and transients. Exhaustive tests were conducted by firing arc welders and large frequency-converter type machines close to the controls. In fact, the controls were placed inside the throat of a machine delivering 300,000 amp without affecting the operation of the timing controls.

Control System Circuits

The complete control system for a specific machine consists of a number of basic types of circuits which are actually very simple. These are: (1) counting and decade transfer circuits, (2) function stepping circuit, (3) gating circuit, and (4) valve control circuit.

Counting and Decade Transfer Circuit

Figure 6 illustrates the above circuit. Pulses from a pulse-forming network are applied to the unit-counting Dekatron and conduction is transferred from cathode to cathode. When the glow is formed at cathode 10, the voltage drop developed across its cathode resistor will lift the potential on the grid of the 12AX7 so that it will conduct. The conduction of the 12AX7 through transformer TR-52 generates a pulse across the secondary. This pulse is delivered to the guides of the succeeding tube in order to count by tens. A pulse-forming system of this type is used to transfer the count from one decade to the next.

Function-Stepping Circuit

At the end of the count when we reach the last cathode of the last Dekatron, a pulse is formed which is delivered to the sequencing or function-stepping circuit, one form of which is shown in Fig. 7. A negative pulse is delivered to the grid of the 6AN5 which momentarily stops conduction of the 6AN5 and any one of the 2D21's which may have been firing. Suppose the first 2D21 had been firing—the grids of all other 2D21's in the chain are held negative by the voltage drop across the 6AN5. The condenser between the 2D21 which is firing and the grid of the next tube in line is held at a low voltage level. With the stopping of con-

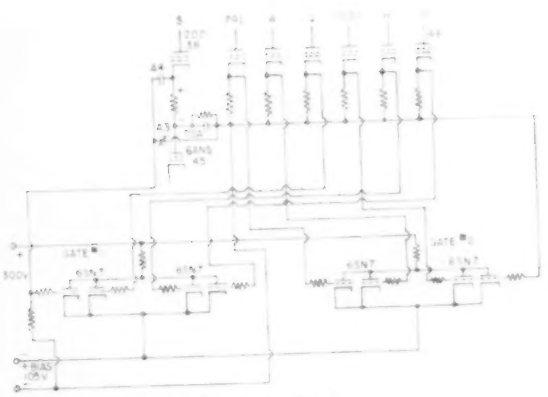

Fig. 9 Sequence and gating circuits

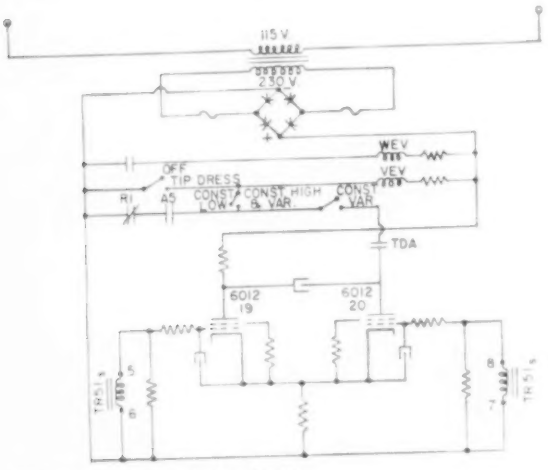

Fig. 10 Valve initiation circuit

duction of the 6AN5, the plate of the 2D21 is brought to the B plus potential and the condenser starts charging through the plate resistor of the tube which had been firing and the grid resistor of the tube next in line. A positive pulse is developed across the grid resistor so that as soon as the grid of the 6AN5 becomes conductive again this second 2D21 will fire. With each succeeding pulse directed to the grid of the 6AN5, the conduction will step from one 2D21 to the next in line.

Gating Circuit

Each gate consists of a section of a dual triode tube whose grid cathode circuit includes a fixed bias plus a resistor in the cathode circuit of one of the stages in the sequence of function-stepping circuit (Fig. 8). When the function-stepping circuit is resting in the stage to which this gate is connected, the voltage drop across the cathode resistor in this stage brings the grid of the 6SN7 to the conducting region. The resultant voltage drop across the plate load resistor is then applied to the circuit being controlled by the gate.

There are two gating circuits (Fig. 9). Gate No. 1 is used to control pulses which are delivered at line frequency rate to the input circuit of the unit Dekatrons used for general machine function control. Gate No. 2 is used to control the pulses delivered to the Dekatron control circuit which forms the cool, heat and current decay intervals used for firing the rectifier in the main circuit of the welding machine. Pulses generated at the end of each weld impulse are delivered to one-half of the pulse-forming network which drives the unit Dekatrons in the general machine function control. These pulses are generated, of course, only during the welding periods when Gate No. 1 is closed and Gate No. 2 is opened. Gate No. 1 is opened only during those functions which require counting cycles at line frequency rate, such as squeeze time. When the function-stepping circuit is resting in the squeeze-function stage, the voltage drop developed across the cathode resistor in this stage brings the grid of the 6SN7 gate to the conducting region so that pulses are formed in the output circuit of the pulse-forming network. The squeeze, quench, hold and off stages are tied to Gate No. 1. Preheat, weld and postheat stages are tied to Gate No. 2. Whenever the function-stepping sequence is resting in a stage tied to Gate No. 2, pulses will be delivered at line frequency to the cool, heat and current decay Dekatron system, and automatically, pulses will be delivered to the pulse-forming network of the general-function Dekatrons at the end of each heat time.

Valve Control Circuit

In resistance-welding machines, it is necessary to operate valves which control the air supply to the pneumatic cylinders which apply force between the elec-

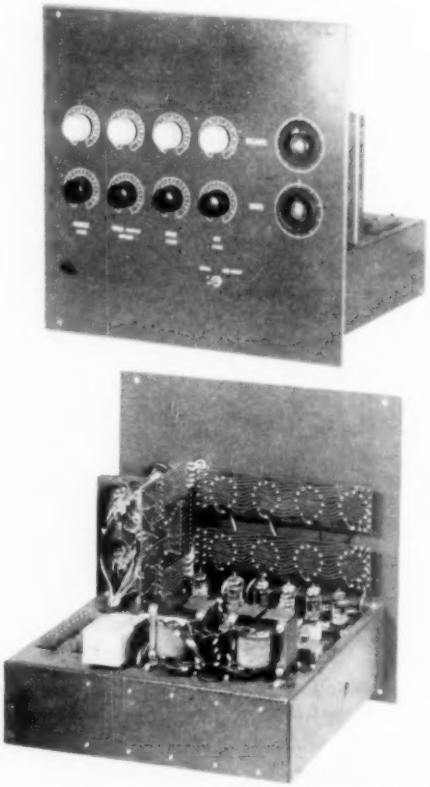

Fig. 11 Front and rear view of "squeeze-weld-hold-off" function chassis

trodes. The electrovalves are controlled by the circuit shown in Fig. 10. Here again we have a flip-flop circuit with a resistor in series with the plate of one of the tubes, and the valve coil in the plate circuit of the second tube. With tube 19 conducting, the electrovalve is de-energized. When a pulse is delivered to the grid of tube 20, the conduction will be transferred to tube 20 and the electrovalve will be energized. This pulse is obtained from the forge-delay circuit. When it is desired to switch to tube 19 again, a pulse is delivered to the grid of tube 19.

The various elements of the control have been arranged according to function and mounted in standard rack type units as shown in Fig. 11. This chassis is one used for controlling the four functions of *squeeze, weld, hold* and *off* up to a count of 100 cycles or impulses. Groups of these chassis may be combined to give the desired control functions as required on a particular machine. For example, Fig. 12 is a picture of a spot welder having 7 sequential functions.

The top chassis is the forge delay chassis counting to 100 cycles.

Next in line is the cool, heat, current decay chassis with a capacity of 10 cycles for each function.

Next is the squeeze, weld, hold, off and below the preheat quench and postheat chassis. Only four chassis are used in the complete control.

Machines that do not require recompression or the additional functions would have only two chassis. If at a later date it is desired to add the additional functions, they could be plugged into position.

Figure 13 is a photograph of a seam welder having 9 sequential functions a cool, heat and current decay panel, and a recompression delay panel. The upper panels are the same as those shown on the spot welder.

Summary

To summarize, the results of our research have been gratifying and have made possible the production of controls having the following characteristics:

1. A control which is fully electronic in operation. Relays are used only for safety and initiation circuits.
2. A control in which only one counting unit is used for all sequential functions no matter how many functions are required.
3. A control which is insensitive to strong magnetic fields, line transients or line voltage changes.
4. A control which is free from all timing calibration adjustments.
5. A control having absolute repetitive accuracy.

The soundness of the approach discussed has been demonstrated by the outstanding results obtained with the many seam and spot welders put into critical welding service in the aircraft industry and by the general acceptance of the idea by users and its adoption by manufacturers of resistance welders and controls. This new development in precision control is one more step in the direction of changing the *art* of resistance welding to the *science* of resistance welding.

Fig. 12 Spot welder with Dekatron control

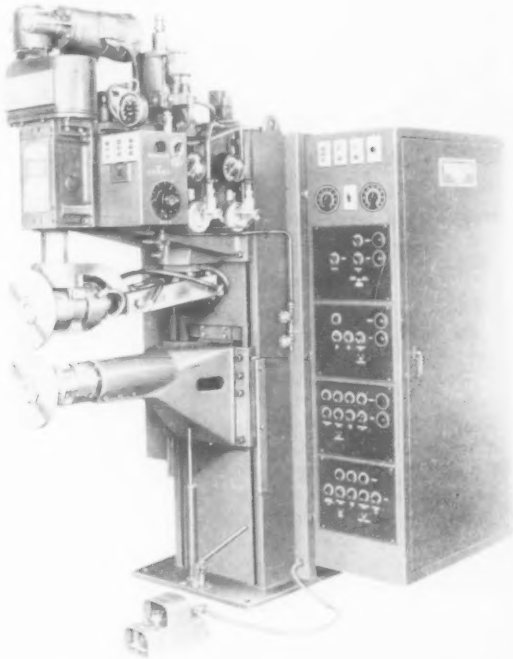

Fig. 13 Seam welder with Dekatron control

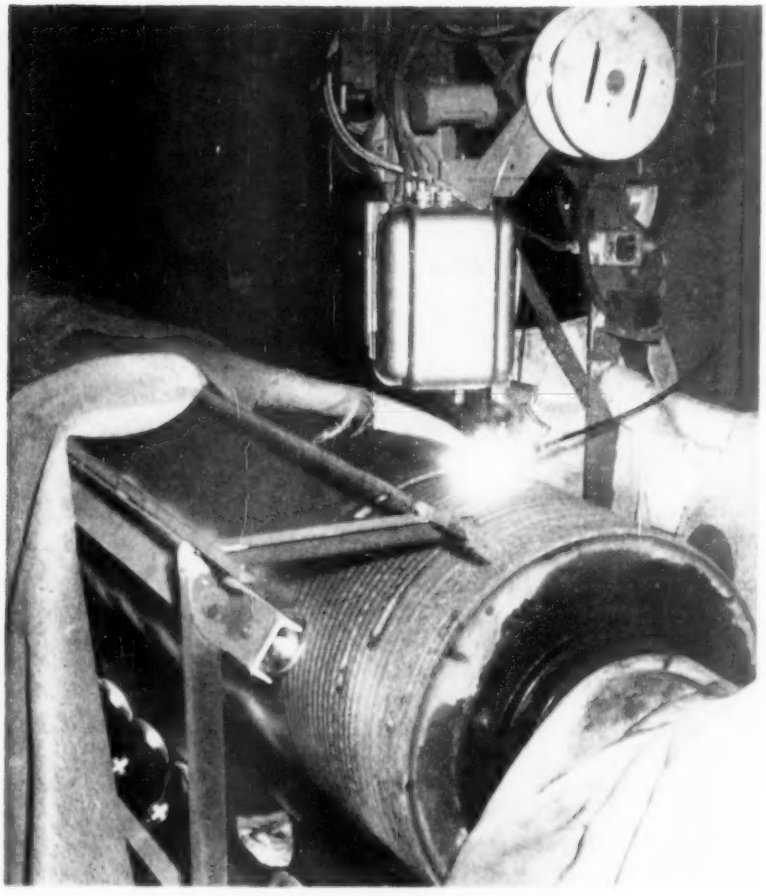

Fig. 1 Nickel surfacing of cast-iron paper rolls with the inert-gas consumable-electrode process and cold-wire addition. The roll is mounted between centers and heated with infrared lamps

MECHANIZED SURFACING WITH ALLOY MATERIALS

Inert-gas-shielded and submerged-arc mechanized processes found advantageous for depositing a variety of surfacing materials including alloys not available as standard welding wire

BY R. S. ZUCHOWSKI AND J. H. NEELY

INTRODUCTION. Surfacing is becoming increasingly important as a production tool. As reported some time ago, mechanized equipment is available for use with any of several processes — oxyacetylene, inert-gas tungsten-arc, inert-gas consumable-electrode or submerged-arc.* For the most part, however, the use of these processes has been restricted to applications involving only a few standard materials. Mechanized surfacing with "tailor-made" alloy materials has not been widespread.

There has always been a need for depositing alloy materials with one or all three of the following characteristics: good abrasion resistance, high impact values and ability to resist corrosion. To obtain deposits with these characteristics, many fabricators have had to use manual surfacing methods because of the unavailability of some alloys in a usable form for mechanized surfacing. Recent developments have, however, extended the number and types of alloy materials that can be deposited with mechanized surfacing. As a result, fabricators are no longer limited to the use of manual surfacing with its high cost, inconsistent quality, and low speed.

This paper focuses attention on three processes, each of which has its place as a production tool. They are: (1) inert-gas tungsten-electrode hard surfacing with the addition of tungsten carbide powder, (2) the inert-gas consumable-electrode process with cold-wire addition, and (3) submerged-arc surfacing with any one of several techniques and with or without powder-alloy additions.

Each of these processes may be used to deposit a variety of materials, including alloys not available as standard welding wire. When these processes are used, better quality deposits and higher deposition rates are obtained at less cost than with other methods.

Inert-Gas Tungsten-Arc Surfacing

Use of the inert-gas tungsten-arc process on a mecha-

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Presented at AWS 1957 National Spring Meeting, Philadelphia, Pa., April 8-12.

* Koopman, K. H. and Zuchowski, R. S., "New Surfacing Techniques," presented at the 1955 AWS National Fall Meeting in Philadelphia, Pa., and published in THE WELDING JOURNAL, 35 (7): 665-671 (1956).

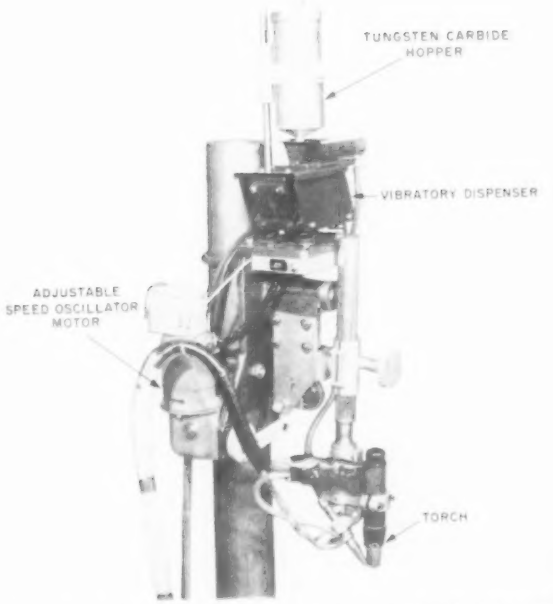


Fig. 2 Special inert-gas tungsten-arc hard-surfacing machine

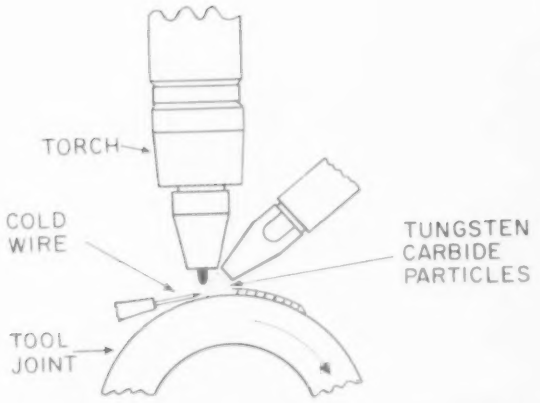


Fig. 3 Relationship of inert-gas tungsten-arc torch, nozzles and work

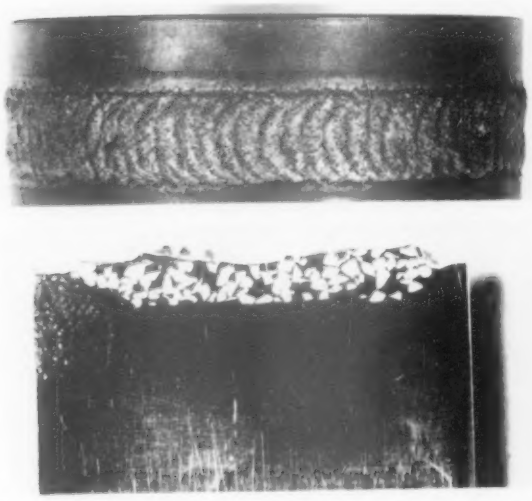


Fig. 4 Surface and cross-sectional view of tungsten-carbide band made with the tungsten-arc process, using direct current, straight polarity

nized basis for depositing tungsten carbide serves as a good example of recent trends in surfacing with alloy materials. Tungsten carbide has extremely good abrasion-resistance properties. It is, however, extremely brittle. The inert-gas tungsten-arc process provides a means to utilize the abrasion-resistant properties of this material while overcoming the disadvantage of brittleness. This is achieved by producing a heterogeneous deposit—that is, a deposit which contains the tungsten-carbide particles uniformly dispersed in a strong and tough matrix. Very little of the tungsten carbide melts; its particles retain their sharp edges when embedded in the softer base material. When adding the tungsten carbide, auxiliary or cold wire can also be added to obtain any desired properties in the matrix of the deposit. The use of auxiliary or cold wire also tends to reduce cracking on those applications where the base material is a high-carbon alloy. With other electric-arc processes, a major portion of the tungsten-carbide powder alloys with the matrix, forming a brittle deposit which will chip or crack under light impact.

One application where this process is used quite extensively is in the hard surfacing of tool joints used on oil drill stems. In this application, bands of tungsten carbide are deposited circumferentially on the tool joints. Usually one or more bands are applied, either by using a stringer-bead technique or oscillation. The oscillating method is preferred, because it provides better tungsten-carbide distribution throughout the deposit; in some cases, however, auxiliary filler wire is used to alter the matrix to satisfy specific requirements. Equipment for this application is shown in Fig. 2. It includes an inert-gas tungsten-electrode torch, an oscillating device and a vibratory dispenser for feeding tungsten-carbide particles into the arc zone at a controlled rate. Both the torch and the tungsten-carbide nozzle (and auxiliary wire when used) are oscillated as a unit to produce a bead up to 1¼ in. wide, depending on application requirements. The relationship between the tool joint and the tungsten-electrode torch, the tungsten-carbide nozzle and the auxiliary wire (when used) is shown schematically in Fig. 3. It should be noted that the tungsten-carbide particles are fed into the weld puddle just before it solidifies, thereby minimizing the melting of these particles.

Typical results are illustrated in Fig. 4. The hard-surfacing deposit shown was made on a tool joint with an oscillating technique, straight polarity direct current at 325 amp and 12 volts. Travel speed was 10 ipm. The frequency of oscillation was 70 to 80 cpm, and tung-

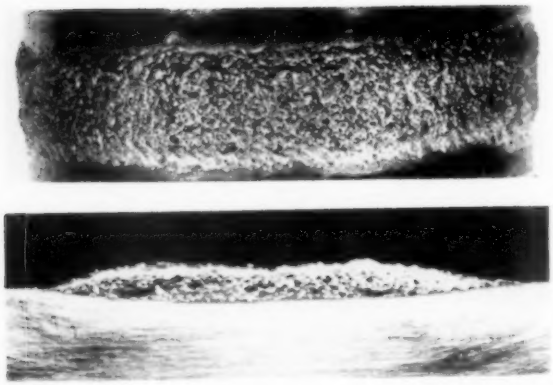


Fig. 5 Surface and cross-sectional view of tungsten-carbide band made with the tungsten-arc process, using alternating current, high frequency

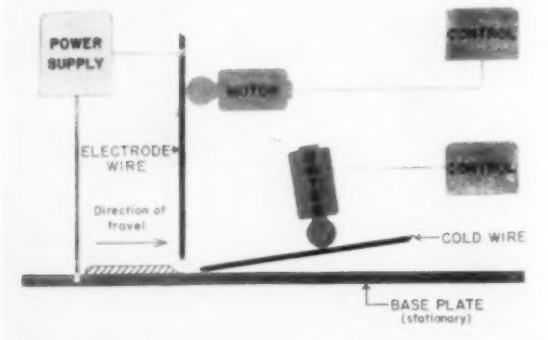


Fig. 6 Schematic for surfacing with the inert-gas consumable-electrode process and cold-wire addition

sten-carbide particle size was 20 on 30 mesh. Argon was used at a rate of 35 cfh. Preheating at 600° F and post-heat treatment at 1000° F were used to reduce cracking in the medium carbon-steel base material. Under the above conditions, the tungsten-carbide particles retained their sharp edges, indicating that very little melting of the particles occurred. Similar results may be obtained using alternating current with high frequency as shown in Fig. 5. Deposits are wider with less penetration. Generally, direct current is preferred.

The quality of tungsten-carbide deposits obtained with mechanized inert-gas tungsten-electrode hard surfacing is comparable to the quality of deposits obtained with the oxyacetylene process, and higher speeds are obtained. The tungsten-electrode process is preferred to flux-coated electrode or submerged-arc surfacing for producing tungsten-carbide deposits since—unlike the latter two—it does not melt the tungsten-carbide particles during their transfer to the weld puddle.

While not described in this paper, the versatility of mechanized inert-gas tungsten-electrode surfacing is such that it can be used to deposit a variety of alloy

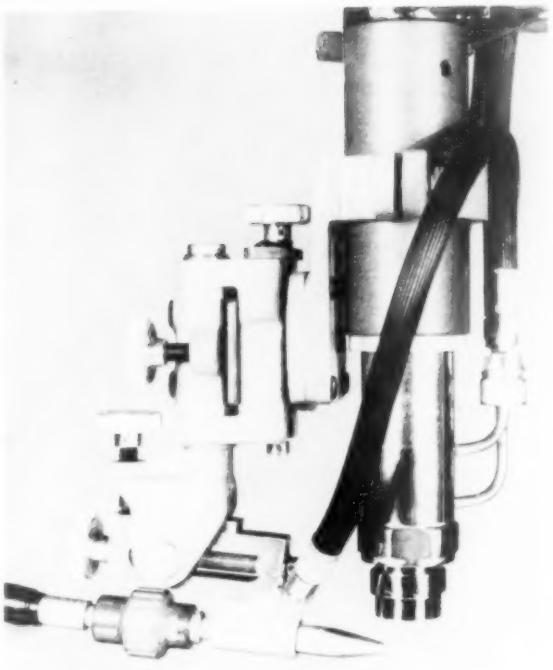


Fig. 7 Cold-wire attachment mounted on an inert-gas consumable-electrode torch

materials available in wire form. These include stainless and alloy steels, bronze, aluminum, copper and nickel.

Inert-Gas Consumable-Electrode Surfacing

Until rather recently, it was generally true that inert-gas consumable-electrode surfacing was characterized by low deposition rates and high base-metal dilution. A relatively new technique has, however, done much to offset these limitations. This technique involves the addition of electrically neutral or "cold" wire into the arc. This wire is melted in much the same way that filler rod is melted during gas welding. In practice, the addition of cold wire has greatly increased deposition rates and reduced dilution.

How inert-gas consumable-electrode surfacing works is shown schematically in Fig. 6. As may be seen, electrode wire is fed into the arc in a normal manner, and an arc is struck from this wire to the work. Cold wire is fed into the arc at a controlled rate. The cold wire is guided into the arc zone by a wire-feed attachment, which permits the relationship between the cold wire and the arc to be varied while the unit is operating. It is helpful to be able to adjust the position of the cold wire with respect to the electrode wire while welding is under way. Furthermore, it should be possible to make these adjustments in almost any direction while the machine is operating—that is, it should be possible to move the wire up or down, from side to side, or in or out. When properly delivered to the welding arc, the cold wire melts in the arc and flows into the puddle.

Equipment requirements for mechanized surfacing

Fig. 8 Surfacing in the flat position with stainless steel using the inert-gas consumable-electrode process with cold-wire addition

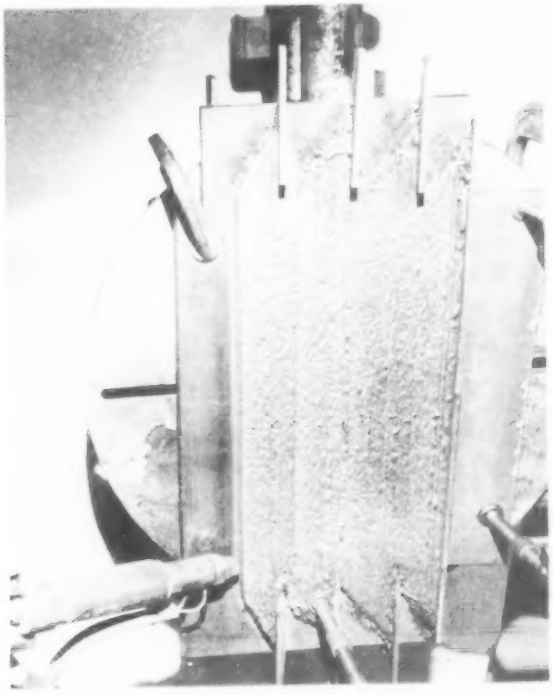


Fig. 9 Surfacing in the vertical position with stainless steel using the inert-gas consumable-electrode process

are basically the same as for mechanized welding. Equipment includes a torch, a wire-feed mechanism to supply wire through the torch, welding controls, a method to move the work or welding head, a suitable source of welding power and adequate supplies of argon and water. In addition, the only other items of equipment required for surfacing are (1) the equipment to supply and position cold wire as it is fed into the arc, and (2) usually a device to oscillate the torch and cold wire. Figure 7 is a photograph of an attachment with knobs for positioning the cold wire while the unit is in operation. In addition, provision is made to water cool the attachment, although this is not required for the majority of applications. When welding currents of 400 amp or more are employed, however, water cooling is usually advisable.

In most applications, the amount of cold wire added to the arc ranges from 0.5 to 1.5 times the amount of electrode wire which is used. The addition and consequent melting of cold wire absorbs some heat from the arc. This reduces penetration into the base metal. In addition, the amount of metal deposited is increased. The result is that the combination of reduced penetration and increased metal deposition greatly reduces dilution.

The addition of cold wire at 0.5 to 1.5 times the electrode wire feed rate increases the total deposition rate by a factor ranging from 1.5 to 2.5. This means that, where normally a deposition rate of 14 lb per hr could be obtained, a deposition rate of 21 to 35 lb per hr is now possible. Another advantage is that the puddle is chilled by the addition of cold wire. The puddle then becomes more sluggish with less tendency to run downhill when surfacing cylindrical objects.

The significance of cold-wire addition with inert-gas consumable-electrode surfacing can perhaps best be viewed against the background of actual applications. One such application involves the mechanized surfacing of cast-iron paper mill rolls, using nickel. Previously this had been done manually. Attempts were then made to surface these rolls with mechanized methods other than the inert-gas consumable-electrode process with cold-wire addition. All were unsuccessful, however, in that high dilution of the base metal resulted and cracking occurred. Selection of the consumable-electrode process with cold-wire addition eliminated this difficulty.

The actual operation is shown in Fig. 1. A $\frac{1}{2}$-in. buildup of nickel is being deposited in two passes on a cast-iron roll approximately 14 ft long and 31 in. diam. In this application, the inert-gas consumable-electrode torch is oscillated while cold wire is fed into the arc. The rolls are turned at a surface speed of about 9 ipm while the welding head automatically travels along the length of the work. The rolls are maintained at a temperature of 150° F by the use of heating lamps along the bottom of the roll. The process, once started, is fully automatic. The operator merely changes the coils of wire as required. In this application, a current of 350 amp d-c reverse polarity is used to deposit 19 lb of nickel per hr. Argon consumption is 40 cfh. The torch is oscillated at a frequency of about 48 cpm over a width of $1\frac{1}{8}$ in. By using mechanized inert-gas consumable-electrode surfacing with cold-wire addition, costs were reduced 35% below the costs for manual surfacing.

It is often desirable to surface carbon steel with stainless steel to combine the corrosion resistance of stainless steel with the mechanical properties of carbon steel. Figure 8 shows a 3-in. carbon-steel plate surfaced with a

$\frac{1}{8}$-in. layer of Type 308L stainless steel. The composite plate has the corrosion resistance of stainless steel but costs less.

The stainless-steel deposit illustrated in Fig. 8 was made in the flat position with standard inert-gas consumable-electrode welding equipment and cold-wire addition. An oscillator moved the tips of both wires transversely to the direction of travel with a simple harmonic motion. In this operation, the frequency of oscillation was 60 cycles per minute while forward travel speed along the plate was 4.2 in. per minute. When using 390 amperes direct current reverse polarity at 30 volts, a deposition rate of 24.8 lb per hour was obtained. Cold-wire addition was the source of 40% of the metal deposited; 60% was derived from the electrode wire. Shielding gas was used at a rate of 40 cfh and consisted of argon with 1% oxygen. The dilution of each pass was about 24%.

Figure 9 shows a carbon-steel plate surfaced in the vertical position with stainless steel. Mechanized inert-gas consumable-electrode equipment is shown without the cold-wire attachment. Using this setup, surfacing in the vertical and inclined positions is easily accomplished even though with traditional techniques all automatic surfacing has been confined to the flat or nearly flat position. Cold wire may be added on plate inclined from the horizontal by as much as 75°, although on vertical plate it is usually not desirable to add cold wire. In this view, a $\frac{1}{8}$-in. stainless-steel overlay was made on a vertical 3-in. plate. Surfacing was performed with the torch oscillating and traveling across the plate in a horizontal direction. This particular sample was deposited at a rate of about 15$\frac{1}{2}$ lb per hr with a current of 340 amp d-c reverse polarity, using a conventional power supply and voltage control welding equipment.

Mechanized inert-gas consumable-electrode surfacing with cold-wire addition is equally as applicable for depositing copper as for depositing nickel or stainless steel. Figure 10 shows a 155-mm shell surfaced with a copper band. The copper band shown was deposited using the inert-gas consumable-electrode process with cold-wire addition. Copper was used for both the electrode and the cold wire, with 1$\frac{1}{2}$ times more cold wire than electrode wire being consumed. An oscillation of $\frac{3}{4}$ in. was used with a frequency of 80 cpm and 415 amp d-c reverse polarity at 27 volts. The shielding gas consisted of argon with 1% oxygen and was used at a rate of 50 cfh. The time required to surface this shell was slightly more than one minute. In this example, base-metal dilution was less than 2%. (Experimentally, copper overlays have been deposited at rates as high as 100 lb per hr. At these high deposition rates, however, base-metal dilution is in the order of 5%.)

Developments in Submerged-Arc Surfacing

Several techniques have been developed to extend the use of the submerged-arc process for mechanized surfacing with alloy materials. Broadly speaking, these may be classified as: (1) series-arc techniques and (2) oscillating techniques.

Series-arc techniques usually use two welding wires. Oscillating techniques may use a single-wire or two wires connected in electrical parallel. Either may be used to obtain deposits with specific analyses as required by the user. Either may be used with powder alloys which can be fed directly into the weld puddle to alter its chemistry even further.

Series-Arc Techniques

An understanding of series-arc techniques may possibly best be gained by reference to Fig. 11 which is a schematic representation of equipment requirements. Two welding heads and welding controls are required — and, of course, a suitable power supply and two electrode wires. The two electrode wires are electrically connected in series with the power supply; there is no welding power connection to the base plate. In operation, the current path extends from one wire to the other through the molten deposit and fused submerged-arc welding composition.

The equipment is assembled so that the wires inter-

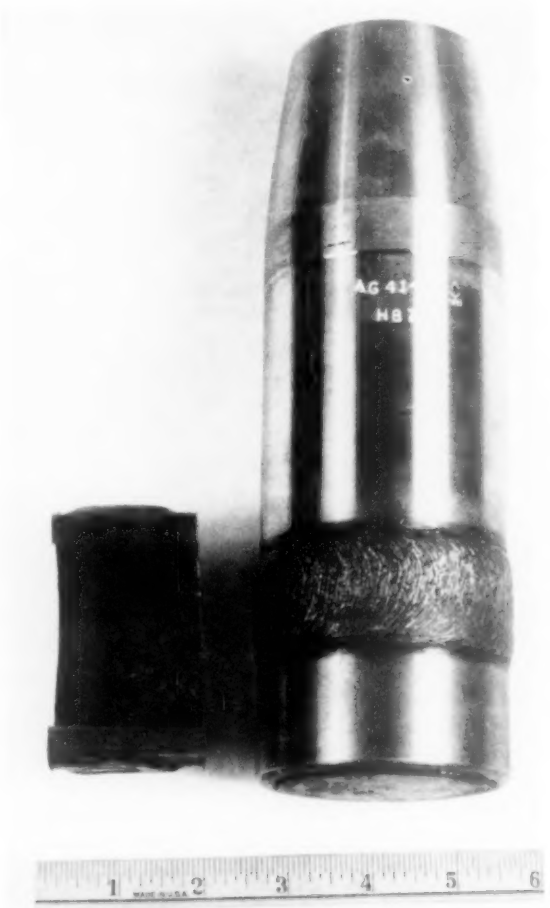


Fig. 10 Deposit of a copper rotating band on a 155-mm artillery shell made with the inert-gas consumable-electrode process and copper cold-wire addition

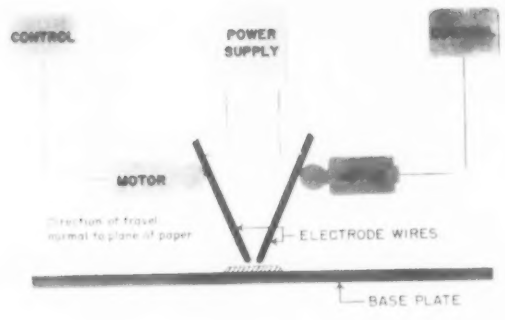


Fig. 11 Schematic for surfacing with the submerged-arc series-arc technique

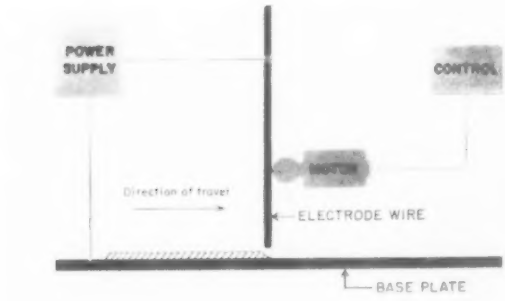


Fig. 12 Schematic showing single-wire setup for submerged arc surfacing with or without oscillation

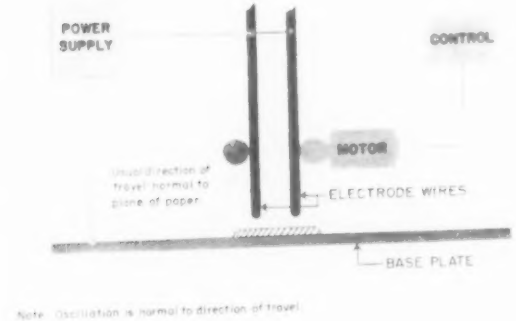


Fig. 13 Schematic showing parallel connection for two-wire submerged-arc surfacing with or without oscillation

sect at an angle of approximately 45°. The intersection of the two wires is usually maintained about $\frac{5}{16}$ to $\frac{1}{4}$ in. above the base metal. Note that the plane of the wires is transverse to the direction of travel, resulting in minimum dilution.

This technique has a major advantage: very high deposition rates with very low base-metal dilution. The technique is used primarily for depositing the more expensive alloys such as stainless steel. It produces a high-quality deposit. Although slightly more complicated than a single-wire system, the additional complications are justified by its superior results.

Since two wires are fed into the welding zone, it is possible to use wires of differing chemical compositions to produce a deposit of a third composition. Alloys in the form of powder have also been used with series-arc techniques to produce deposits with special chemical compositions. Equipment for dispensing the alloys is usually an accessory item. With the series-arc technique, alloy powders are dispensed with the same equipment as previously described in the inert-gas tungsten-arc process. However, they are dispensed in front of the welding arc rather than behind. The arc passes over the powders and melts them into the deposit where they become alloyed.

In one application, the series-arc technique is used to clad the entire inside surface of a pressure vessel with a $\frac{1}{8}$-in. thick layer of Type 308L stainless steel for corrosion protection. This is done in two to three layers. The series-arc technique was selected as an economical means for cladding the vessel, because it provides both low base-metal dilution and very high deposition rates.

For the first layer, the a-c welding current is maintained at 400 amp to minimize base-metal dilution. On the second and subsequent layers, however, the welding current is increased to approximately 800 amp, thereby doubling the deposition rate to approximately 50 lb per hr.

Oscillating Techniques

The schematic of a single welding wire setup is illustrated in Fig. 12. The single-wire system, which is by far the most commonly used mechanized surfacing method in this country today, consists of a single welding wire driven by a single welding head and control. Figure 13 illustrates a parallel-welding setup that is, one wire-feed motor driving two electrically-parallel wires.

Either the single-wire or parallel techniques can be used with or without oscillation. With either of these techniques, alloy deposits can be obtained either by using standard alloy wires, by adding alloy in powder form, or by obtaining the alloy from specially prepared submerged-arc compositions. The alloys in these special compositions are transferred to the deposit under the action of the welding arc.

As shown in Fig. 14, submerged-arc oscillating equipment consists of a standard wire feeder oscillated by an adjustable speed motor through a cam-link system. Oscillation is a simple harmonic motion perpendicular to the direction of travel. One advantage of the oscillating technique is a slightly lower dilution than obtained with a single wire or a parallel technique. Another is that this technique is suitable for making wide, smooth deposits in one pass. If made with the single-wire or parallel techniques without oscillation, the same

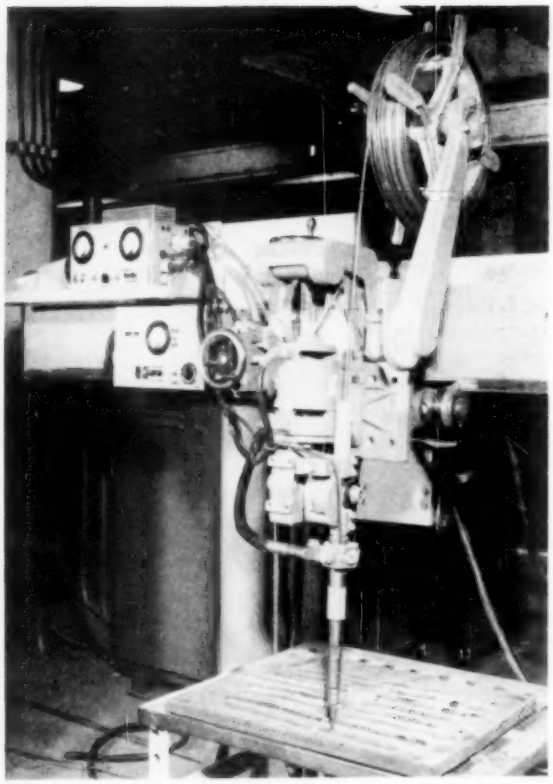


Fig. 14 Equipment for submerged-arc surfacing with oscillation

deposit would require several passes.

The oscillating frequency of this equipment can be varied up to 90 cpm, and the oscillation varied up to approximately 3 in., a 2-in. oscillation being typical. After the deposit width is established, the forward travel speed is adjusted to produce a buildup of the desired thickness. For 2-in. wide deposits, it is generally between 3 and 5 ipm.

Figure 15 shows a typical hard-surfacing deposit made with the oscillating technique. It is a deposit such as might be used for hard surfacing front-end wear parts of earth-moving equipment and illustrates the versatility of the oscillating technique. The leading edge (the area of greatest wear) was hard surfaced at a slow forward speed and high rate of oscillation to produce a solid 1½-in. wide deposit approximately $\frac{3}{16}$ in. thick. The backing area where wear is less severe was hard surfaced in two passes at a much slower oscillating frequency and a much higher forward speed to produce the criss-cross type pattern. The far pass was made without oscillation.

Another application of the oscillating technique is illustrated by Fig. 16 which shows pellet rolls before and after hard surfacing. In this instance, a 3½-in. wide deposit was applied to the larger 7-in. diam roll in two passes, whereas only one pass was required to hard surface a 2½-in. wide surface on the smaller 5-in. diam roll. A mild-steel wire used in conjunction with a submerged-arc hard-surfacing composition produced a deposit hardness of 58 Rockwell C. Welding current was 320 amp d-c straight polarity, 30 volts, and travel speed was 2½ ipm.

In general, it is often difficult or impossible to produce crack-free stringer beads with high-carbon or high-alloy material. The use of oscillation does much to reduce this tendency—a reason why the oscillating technique was used on the pellet rolls. Austenitic manganese steel deposits are especially susceptible to cracking when applied with the stringer bead technique. When the oscillating technique is employed, cracking is reduced or eliminated as shown in Fig. 17 where use of a standard submerged-arc composition in conjunction with oscillation produced a crack-free and relatively-smooth deposit.

In some cases, it may be desirable to alter the chemistry of a deposit. As mentioned previously, this can be easily done by employing powder alloys. Figure 18 shows the necessary equipment consisting of a powder dispenser mounted on the oscillating mechanism. In this example, the alloy powder is deposited on the base metal ahead of the submerged-arc composition. The powder is melted under the welding arc and alloyed in the deposit.

Cold-wire addition may also be used with an oscillating technique for mechanized submerged-arc surfacing

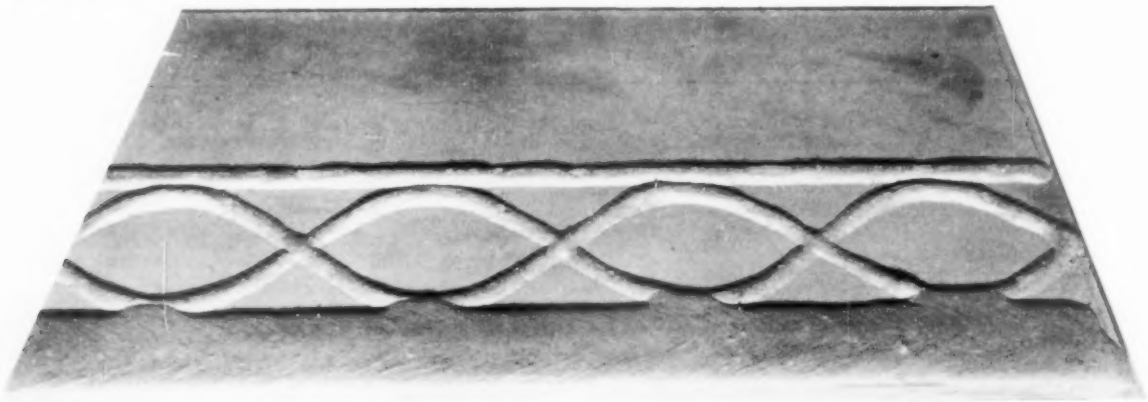


Fig. 15 Criss-cross pattern obtained with submerged-arc surfacing using a special oscillating technique

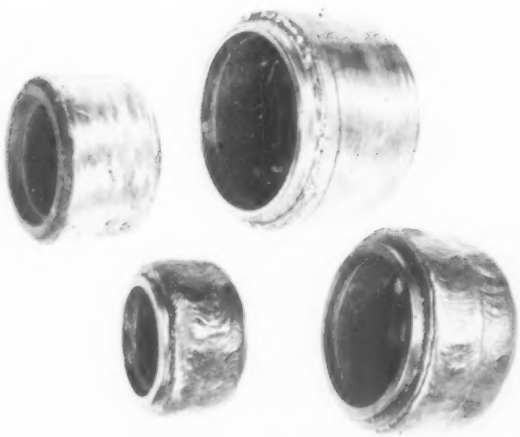


Fig. 16 Pellet rolls before and after hard surfacing with the submerged-arc process and oscillation

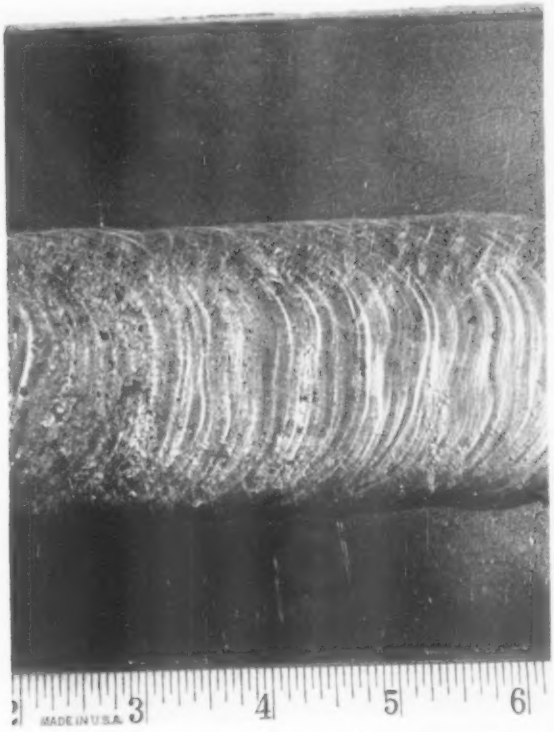


Fig. 17 Manganese steel deposited on manganese steel by submerged-arc surfacing with oscillation

with alloy materials. Equipment for this is shown in Fig. 19. By using cold-wire addition, various combinations of welding wire can be used to get a desired deposit. A larger variety of compositions can be obtained by employing cold-wire addition in conjunction with powder alloys. Although this complicates operation of the equipment, it may provide the only means available for obtaining an overlay with a particular chemical composition.

Conclusion

There are several mechanized surfacing processes available for depositing practically any desired alloy composition. Each costs less and produces more desirable results than manual surfacing. Finally, the use of multiple welding wires and powder alloys furnish means by which the composition of alloy deposits can be altered even further to suit application requirements.

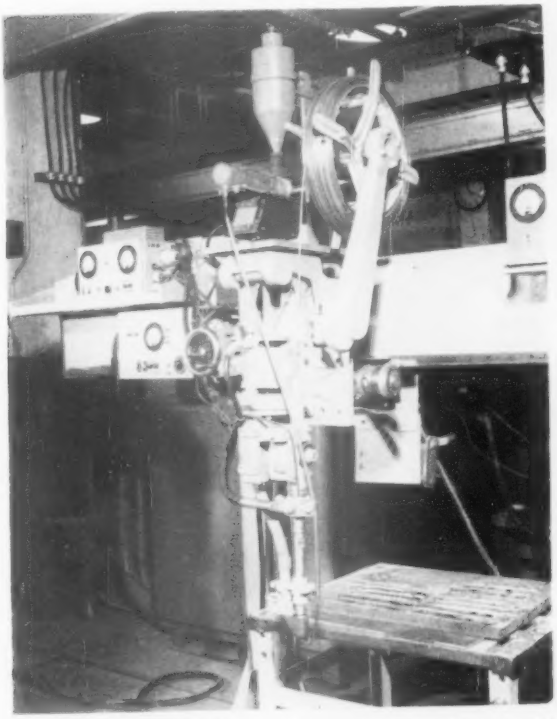
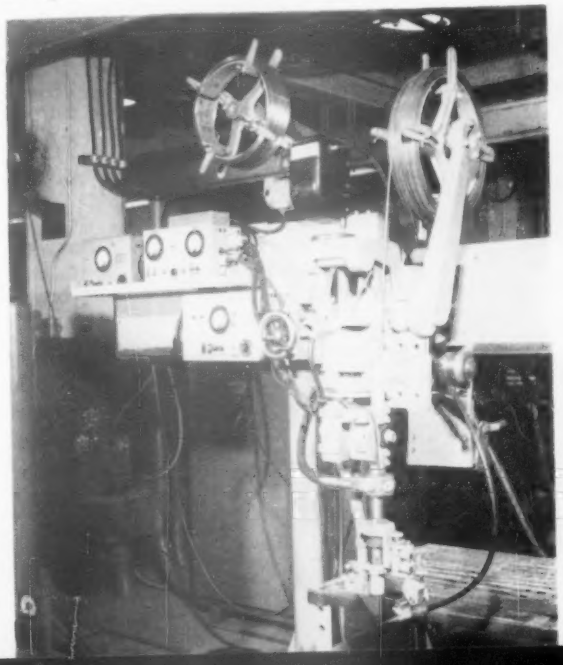


Fig. 18 Equipment for submerged-arc surfacing with oscillation for hard surfacing with alloy powders

Fig. 19 Equipment for mechanized submerged-arc surfacing with cold-wire addition and oscillation



A METHOD FOR EVALUATING MATERIALS USED IN PENETRANT FLAW DETECTION

The use of a pressure-type device that provides a standard fissure suitable for evaluating penetrant flaw-detection materials is proposed by the author

BY R. W. MILLER

This pressure-type device provides a "standard fissure" suitable for evaluating penetrant flaw detection materials

SUMMARY. In the application of a penetrant test there has been a question in the minds of the persons doing nondestructive testing as to whether the penetrant materials made available to them possess the maximum sensitivity. Thus, there is a requirement for quality control or inspection testing at the user's location.

A pressure-type device that provides a "standard fissure" suitable for evaluating penetrant flaw-detection materials is presented. The presence or absence of crack indications, characteristic of the type of penetrant applied to the jig, serves as a criterion concerning the suitability of the penetrant tested.

Introduction

Since they require no expensive equipment, penetrants have done much toward extending the practice of nondestructive testing to the many welding and repair shops throughout this country. Operating on a purely physical basis of the liquid entering a crack, pinhole or other opening in the surface, penetrants work equally well on ferrous or nonferrous assemblies. While the penetrant method of flaw detection is not limited to the inspection of weldments, the portability and ease of application make it an ideal tool for the inspection of weldments in the field as well as in the shop. One noteworthy application is the inspection of heavy weldments where it is desirable to check periodically as welding progresses. With its high degree of sensitivity the penetrant method of flaw detection is proving a valuable supplement to the many nondestructive testing methods now used by industry.

In the application of nondestructive testing methods there arises, on occasion, some question of the accuracy of the test equipment or the sensitivity of the technique employed. Users of nondestructive testing equipment have been aware of this problem and, with the help of various authoritative groups, have developed standardized procedures for evaluating the equipment and techniques employed in many of the nondestructive testing methods. An example is the penetrameter used to check the adequacy of radiographic techniques.

Since the advent of the popular dye-penetrant methods of flaw detection, industry has been seeking a comparable procedure for testing and evaluating the performance of penetrant materials. The Navy, a large user of nondestructive testing, has also been aware of this requirement for quality control of penetrant materials. Accordingly, the U. S. Naval Engineering Experiment Station was authorized by the Navy Department's Bureau of Ships to develop a performance test suitable for determining the relative sensitivity of penetrant methods of flaw detection.

Approach to Problem

In approaching the problem, a study was made of the penetrant-flaw detection methods used for the surface inspection of ferrous, nonferrous and nonmetallic materials. They are, for the most part, extremely sensitive and will produce comparable results when properly applied. The method of application is

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This paper presents the author's personal opinions and assertions which do not necessarily reflect the official attitude of the Navy Department.

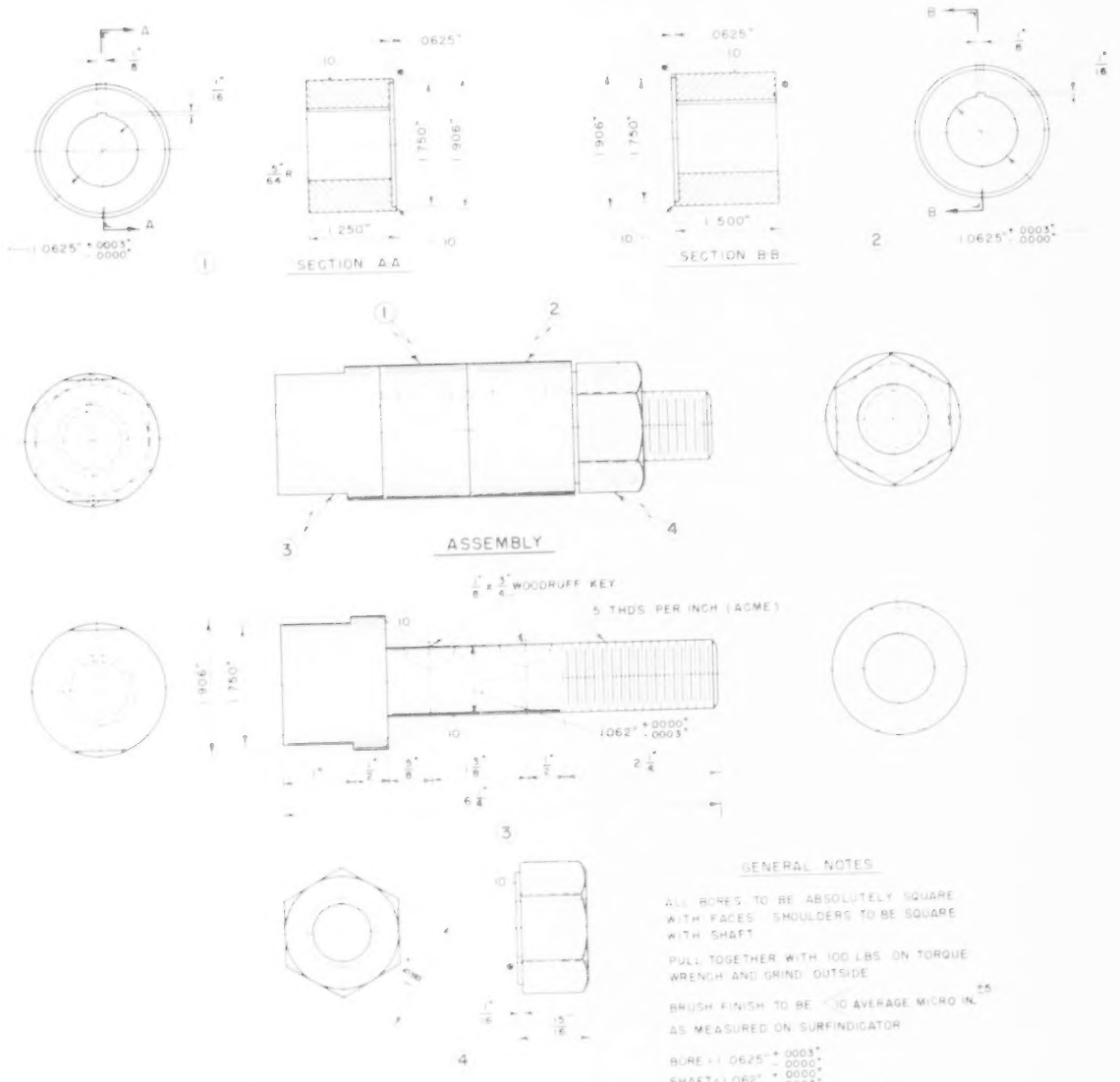
SECTION A-A
SECTION B-B
ASSEMBLY
WOODRUFF KEY
5 THDS. PER INCH (ACME)
GENERAL NOTES
ALL BORES TO BE ABSOLUTELY SQUARE WITH FACES. SHOULDERS TO BE SQUARE WITH SHAFT
PULL TOGETHER WITH 100 LBS. ON TORQUE WRENCH AND GRIND OUTSIDE
BRUSH FINISH TO BE 10 AVERAGE MICRO IN. ±5 AS MEASURED ON SURFINDICATOR
ALL OTHER DIMENSIONS ± .005"
* FACES OVERLAID WITH COLMONOY #4 SURFACING ROD

Fig. 1 Construction details of the penetrant testing device

fairly simple and consists merely of painting the surface of the object to be inspected with a coating of a brightly colored penetrant or a fluorescent penetrant if the examination is to be made under a black light. After allowing time for the mixture to penetrate into any surface crack that may be present, the remaining penetrant is wiped off the surface and a detecting powder is applied to the surface. The penetrant is attracted out of the crack, thereby signaling the location of the otherwise invisible crack. However, in those cases where no crack indications are obtained, some doubts may be entertained as to the sensitivity of the penetrant materials or the technique employed. Thus, a performance test that might be used to determine the sensitivity of the penetrant becomes desirable.

After an investigation of the various approaches to this problem and after inquiring as to the results of attempts by commercial laboratories to solve the problem, it was decided that the best approach was the practical one, namely, to produce a fine, standard fissure. It was felt that this might be accomplished by employing a pressure device designed to produce a fine fissure that would provide some measurement of the penetrant sensitivity. From previous experience it was evident that such a device should be engineered to satisfy the following requirements:

1. The device should provide a reproducible, synthetic fissure of a size suitable for use as a criterion.

2. The material of which it is fabricated should offer the penetrant the same physical conditions as might be encountered in service.

3. The device should be sturdy but not bulky and should be simple in operation.

4. The device should be easily disassembled for cleaning.

Design of Test Fixture

With the above requirements in mind, a pressure-type fixture was designed to produce a synthetic fissure suitable for evaluating the performance of penetrant methods of flaw detection. Details of the fixture are presented in Fig. 1. The component parts of the fixture are shown in Fig. 2. The device consists of two cylindrical sleeves so designed that when butted together they produce a synthetic fissure. A machine bolt supports the two sleeves and insures proper alignment of the assembly. Pressure may be exerted on the butted tube ends by tightening the nut over the end of the supporting bolt. While the machining demands are not unreasonable, considerable precision is required to insure proper alignment of the parts and to obtain the required surface finish. For this reason all of the bearing surfaces were coated with a hard-surfacing alloy prior to the final machining operations to prevent damage or deformation of those areas, particularly the surfaces forming the synthetic fissure.

Table 1—Viscosity and Surface Tension of Penetrants Tested

Penetrants tested	*Surface tension, dynes/cm*	*Viscosity 100° F, centistokes*
Commercial type	23.5	1.32
Commercial type	25.2	2.16
Commercial type	26.7	3.33
SAE No. 10—Oil mixture*	29.7	32.6
SAE No. 20—Oil mixture*	29.3	64.7

* Red dye color added.

Evaluation Tests

Upon completion of the test fixture, a series of tests was planned to evaluate the testing device and to determine how much pressure should be exerted on the tube ends to compress the opening to a size suitable for use as a criterion. Accordingly, three commercial-type penetrants and two experimental penetrant mixtures were selected for testing to determine whether the device was suitable for detecting variations in penetrant sensitivity. Four tests were conducted for each of the representative penetrant mixtures with a torque load of 30, 100, 200 and 300 ft-lb, respectively, applied to the nut of the fixture. Identical testing procedures were followed for each of the five penetrant mixtures employed. The penetrant was applied to the surface of the test fixture by means of a brush (Fig. 3) and allowed to remain for a period of 10 min. The penetrant was then removed from the surface. This was followed by an application of dry detecting powder. After an interval of 10 min the powdered surface, at the joint periphery, was examined for traces of the penetrant.

As a check of reproducibility, two identical test jigs and two operators were employed in the evaluation tests conducted for the fixture. The indications produced by the test penetrants applied to the synthetic defect were noted and recorded to show the degree of visibility as determined by each operator. Further, to evaluate the testing procedure, two additional observers were requested to view the penetrant indications and record their observations regarding color intensity and visibility. Some attempt was also made to determine the amount of penetration attained by each of the penetrant mixtures by disassembling the fixture and inspecting the bearing surfaces. However, penetration

Table 2—Results of Evaluation Tests

Torque, ft-lb	*Penetrants tested*	*Color indication*			*Visibility rating*				*Remarks*
		Red	*Pink*	*Light pink*	*Very good*	*Good*	*Fair*	*Poor*	
300	Commercial type	X				X			Distinct—good contrast.
	Commercial type	X				X			Distinct—good contrast.
	Commercial type			X			X		Indistinct—poor contrast.
	SAE No. 10—Oil mixture			X				X	Indistinct—very thin indication.
	SAE No. 20—Oil mixture								No indication.
200	Commercial type	X				X			Distinct—good contrast.
	Commercial type	X				X			Distinct—good contrast.
	Commercial type			X			X		Indistinct—poor contrast.
	SAE No. 10—Oil mixture			X				X	Indistinct—poor contrast—thin indication.
	SAE No. 20—Oil Mixture								No indication.
100	Commercial type	X			X				Distinct—good contrast.
	Commercial type	X			X				Distinct—good contrast.
	Commercial type		X			X			Indistinct—fair contrast.
	SAE No. 10—Oil mixture		X				X		Indistinct—poor contrast.
	SAE No. 20—Oil mixture								No indication.
30	Commercial type	X			X				Distinct—good contrast.
	Commercial type	X			X				Distinct—good contrast.
	Commercial type	X			X				Distinct—good contrast.
	SAE No. 10—Oil mixture	X				X			Distinct—good contrast.
	SAE No. 20—Oil mixture								No indication.

NOTE: The results of this table represent the consensus of opinion of two operators, plus two additional observers.

Fig. 2 Testing fixture disassembled showing component parts

Fig. 3 Penetrant to be tested is applied to the "standard fissure" provided by the pressure device

measurements were found to be impractical as the penetrant film was spread too thinly over the inner test surfaces to give positive indications. As a matter of interest in establishing whether any correlation existed between penetrant sensitivity and standard physical properties of the penetrant mixtures, the surface tension and viscosity of the five test penetrants were determined by standard procedures and the values are presented in Table 1.

Upon completion of the tests, the data obtained from each operator were used to compile a single table that represents a consensus of the observations recorded by the group. The results of the evaluation tests are presented in Table 2.

Conclusion

From a study of the performance test data, it is apparent that the fissure opening produced by the 200 ft-lb torque load represents a more severe test of penetrant sensitivity than the fissure opening produced by the 30 ft-lb torque load. However, the torque load, i.e., fissure size selected to serve as a criterion of penetrant performance, may depend upon other factors. While desirable from the standpoint of severity, the 200 ft-lb torque load has one disadvantage in that it tends to produce indications that are extremely narrow in width and of low color intensity. To the inexperienced operator, such borderline indications are difficult to evaluate and lead to differences of opinion regarding their interpretations. Conversely, it is found that the penetrant indications obtained under the 30 ft-lb torque load are of a higher color intensity and of sufficient width to provide a positive indication of penetrant performance. Thus, it can be seen that the human element involved in the interpretation may place some limitation on the size of the fissure selected to serve as a criterion. In view of the limitations imposed by the operator's ability to detect and interpret the penetrant stain and in view of the distinct indications and visibility ratings obtained at the lower torque load, it is considered that the fissure produced by the 30 ft-lb torque is more practicable for use as a criterion for evaluating dye-penetrant methods of flaw detection.

As shown in Table 1, all of the test penetrants employed were of approximately the same surface tension. Since the crack detecting sensitivity of the SAE No. 20 oil mixture was considerably less than the other four mixtures, it is assumed that the surface tension alone is not a controlling factor. For the oil base-penetrant mixture it appears that viscosity may have considerable bearing on the sensitivity of the penetrant. The color intensity of the flaw indication is also considered to provide some measurement of penetrant sensitivity since the visibility of the indication is dependent largely upon the degree of contrast between the penetrant stain and the developer. Accordingly, a penetrant capable of producing an indication having an intense red color is considered more sensitive than the penetrant producing an indication having no color or one of less intense color. The results of the evaluation tests performed for the pressure device and presented in Table 2, show that the device will reveal whether the penetrant has the necessary physical properties to produce an indication at the small test fissure opening and whether the penetrant will retain its original red color under small fissure conditions. Summarily, it is shown by the results presented in Table 2 that the pressure jig provides a practical and ready means of comparing penetrant-test materials. In addition, the device is considered to be useful for training operators in the proper use of penetrant flaw-detection methods and for evaluating the technique employed in the application of such methods.

INERT-GAS TUNGSTEN-ARC BUTT WELDING OF ZIRCALOY-2 TUBES

DISCUSSION BY ROBERT E. ARMSTRONG

The author is to be congratulated upon his excellent contribution to the growing store of welding knowledge of new atomic reactor materials. Almost all of the original development work was carried on in the secrecy of government installations and full and complete information is not readily available. An understandable tendency to seek perfection in an unknown field in much of this early nuclear work must be recognized. Publication of articles, such as this one by Mr. Lingafelter, will provide the basis for realistically evaluating the necessity for the extraordinary precautions considered necessary in the first reactors.

The initial welding development on zirconium and Zircaloy 2 indicated that these materials must be welded in a welding chamber that has been evacuated to 0.03 microns for a minimum of 12 hr, and then back filled with helium to ensure corrosion resistant welds. This method has been successfully used in naval reactor plants with excellent results but it is very expensive and time consuming. We are reasonably sure that these rigid requirements can be safely relaxed, especially for commercial reactors, but we cannot determine the extent until we have accumulated sufficient fabrication and operational experience. Mr. Lingafelter has obtained excellent results with a very simple and economical procedure. When more of these reports are published, I am sure we can safely simplify the procedure of welding zirconium and its alloys.

I was pleased to find the results of 6 months long corrosion tests in 350° C (660° F) water, in addition to the physical properties tests. Without these results, I would question the validity of the procedure. A welding procedure for Zircaloy 2 must not only produce weldments with good physical properties, but must also produce weldments that will withstand the corrosive environment of nuclear service. In most cases, this is high pressure, high temperature water. Long-time corrosion tests are vital to the evaluation of a welding procedure for this material since the selection of welding procedure has a decided influence on the as-welded resistance to high temperature water corrosion. Short-term steam tests are being substituted for long-term water corrosion tests, but I personally am not yet convinced of the validity of extrapolating results of severe short-term tests to predict milder long-term service life.

Mr. Lingafelter has apparently violated all the rules we would consider to be required and yet has produced excellent weldments. He did not pickle either before or after welding, yet he has apparently obtained corrosion resistant welds on the tube interior.

In the past we have considered it necessary to pickle all welded surfaces after welding to obtain the best corrosion resistance but recent KAPL tests show that pickling after welding may not be required. We have found the greatest corrosion at the heat-affected zone, rather than on the weld pool, and believe this is caused by the nitrogen picked up on the surface of the weld pool being dispersed throughout the pool while the nitrogen picked up on the surface of the cooler heat-affected zone remains on the surface or is diffused only slightly below it. The nitrogen content of this layer is thus quite high and corrosion is severe. We have welded pieces of material, had them corrosion tested, and found the weld area to be the only area free from corrosion.

Evidently the entire surface was contaminated and welding dispersed these contaminants throughout the entire molten fusion zone to a degree that the concentration was lowered below the corrosion level. I mention this because Mr. Lingafelter's micrographs show the weld zone to be free of corrosion product or attack. I would prefer to see a section of the heat-affected zone as being more indicative of the corrosion resistance.

You may be asking the question of why was it necessary to use such elaborate precautions in welding originally, while the same material can now apparently be welded with only reasonable precautions. I believe the key is in the quality and uniformity of the base metal. Nitrogen content has been steadily lowered by improved processing methods and more nitrogen can now be added during welding without impairing the corrosion resistance of the weldment. The improved uniformity of the base metal means it is no longer necessary to have a procedure that will accommodate the occasional high nitrogen content batch, as it was originally. As the metal producers continue to improve their methods and produce lower nitrogen content material, I believe we will be able to safely relax the rigid requirements we have placed on these welding procedures.

Robert E. Armstrong is associated with Knolls Atomic Power Lab., General Electric Co., Schenectady, N. Y.

Paper by J. W. Lingafelter was published in the March 1957 issue of THE WELDING JOURNAL, 36: 230-235.

We agree with Mr. Lingafelter that Zircaloy 2 is readily weldable. He mentions that full penetration welds can easily be obtained. I would like to mention a phenomenon we have noticed in welding Zircaloy that aids in obtaining full strength welds. This is the phenomenon of "self-welding," "diffusion bonding," "welding without fusion," or what have you. Zircaloy is a very active metal and bonding can be obtained across a clean joint by the application of heat and pressure. Even though melting is not present, grain growth will occur across the interface and a solid joint will result. This phenomenon occurs in welding a butt joint with incomplete penetration or fusion. The molten pool in the fused portion of the joint supplies the heat, and the shrinkage stresses imposed by the solidifying pool supplies the pressure. If the joint was clean to begin with and is kept clean during welding, grain growth will occur across the unfused portion and a completely "welded" joint with incomplete "penetration" will result. This is a great advantage, especially when welding without a backing.

I hope that this excellent paper and the discussions that follow will encourage others to document and publish their experiments and experiences in the field of welding these unfamiliar reactor materials. The more knowledge available, the easier it will be to retain our lead in the atomic energy field.

Discussion by R. E. MONROE AND D. C. MARTIN

Mr. Lingafelter's paper aptly shows the excellent results which can be obtained in welding reactive metals by the use of simple precautions to prevent contamination.

A comparison of the results of tensile tests made on annealed tube and welded and annealed tube indicates low tensile ductility for the welded samples. While some of this difference can be attributed to the higher strength of the beta phase, it is possible that the fine precipitate encountered in Zircaloy-2 microstructures may also lower tensile ductility. This precipitate has been identified as a complex eutectoid of zirconium with iron, chromium and nickel. If this eutectoid is taken into solution by a heat treatment or welding followed by fast cooling, formation of the precipitate can be suppressed. Niemann and Sopher[1] have shown that the effects of this precipitate are most easily observed in a slow-bend test. In regard to this discussion, we have the following questions: (1) were any bend tests made in connection with this work? and (2) was any comparison made of the ductility of single- and two-pass weldments?

Other studies have shown that the thermal cycling in multipass weldments may promote the formation of the precipitate in the first weld passes deposited. However, the thin section of the tubes welded (0.045 in.) may have resulted in high enough cooling rates to suppress precipitation even in the two-pass welds.

The results of the corrosion tests made are certainly encouraging, but it should be pointed out that corrosion attack is generally greater in the weld heat-affected zone. This is shown by the appearance of tan or white oxide films on either side of the weld.

R. E. Monroe and D. C. Martin are associated with Battelle Memorial Institute, Columbus, Ohio.

1. Niemann, J. T., and Sopher, R. P., "Embrittlement of Multipass Welds in Zircaloy 2," The Welding Journal, 35 (1): 27S (January 1956).

AUTHOR'S CLOSURE

As a general introductory comment, I'd like to mention that the welding procedure described in this paper for Zircaloy tubes should not be assumed acceptable for all Zircaloy welding applications. Our particular application was unique and we were able to depart from the standard procedures requiring the use of a welding chamber. Many Zircaloy welding applications require welding in an inert gas-filled chamber. Obviously, each Zircaloy welding application must be analyzed on the basis of criteria set up for each particular case.

No bend tests were conducted as part of the testing program reported in the paper, due to lack of material. However, free bend tests were performed on as-welded and as-received tube samples at a later date, when additional material became available. In all cases, the welded samples showed better ductility than the as-received tube samples.

Over a year's corrosion testing in 350° C de-ionized water has now been accumulated on weld samples. The corrosion resistance still appears to be as good as that indicated for six-month's exposure. It should be pointed out again, that only the tube interior was shielded with helium during welding. The tube exterior was not protected, and some attack has occurred. In its normal operating environment, the tube would not be subjected to corrosive media on its exterior.

I should like to thank Messrs. Martin, Monroe and Armstrong, for their comments. Their information and comments further add to the increasing store of knowledge we are gathering on fusion welding Zircaloy.

CO_2 GAS WELDING PIONEERS IN CONSTRUCTION OF HAVANA TUNNEL

BY I. D. HOLSTER AND H. D. MANN

The construction of a four-lane, 1,500-ft long tunnel under the entrance of Havana harbor is a project of the Société des Grands Travaux de Marseille, a French company, with the fabrication of the steel bottoms sub-contracted to Mecanizadora Agro-Industrial Lamadrid, S. A.

The tunnel will consist of five sections, each about

I. D. Holster and H. D. Mann are Process Engineers associated with the Air Reduction Sales Co.

Fig. 1 Excavated pit in foreground where steel bottom sections are welded in record time with gas-shielded metal-arc process

Fig. 2 Operator ready to make lap weld on steel section

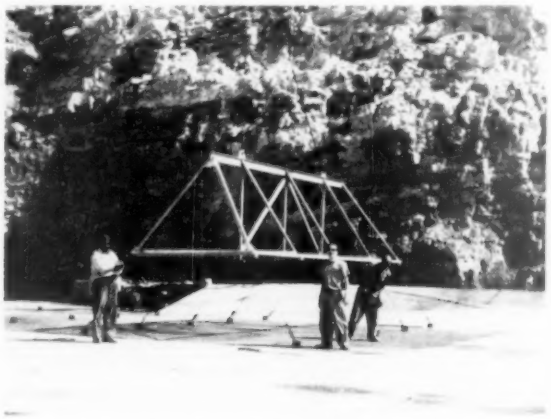

Fig. 3 Crane helps fit bottom plate into place for welding

Fig. 4 Gas-shielded metal-arc process in action making lap joints on Havana tunnel bottom sections with CO_2 gas for shielding. Process reduced manpower requirements by 50%

350 ft in length, 72 ft wide and 23 ft high, weighing approximately 18,000 tons. Built with reinforced concrete, these sections are constructed two at a time in a dry dock at the job site. Completed sections will be floated out.

Steel plate $\frac{5}{32}$ in. thick lines the bottom of each tunnel section and makes a water-tight form where concrete can be poured. The bottoms, composed of 270 sheets, each sheet roughly 4 ft wide and 25 ft long, are welded into larger panels and lifted directly into position by a crane.

They become tunnel bottoms by being lap welded with the gas-shielded metal-arc process, using CO_2 for the shielding gas (Figs. 1 to 4).

Six welders in three shifts complete the final assembly of two bottoms in ten days. Formerly it took 12 welders using stick electrodes 14 days to do the same work.

Five thousand special anchor pieces were also welded. The power sources and water coolers were arranged in a carriage with CO_2 cylinders to make a portable, compact unit.

On the steel bottoms, the two manual guns weld about 9000 linear feet of weld in approximately 200 hr of operation each, consuming 900 lb of $\frac{1}{16}$-in. steel wire.

WELDED TRUSSES REST ON HAUNCHES

Better than 1000 tons of structural steel and 25,000 lb of welding rod were combined in the framework of the municipal Sportscenter at Evansville, Ind. It comprises eight arched and center-pinned 80-ton trusses resting on 14-ton triangular haunches along either side, giving a free span of 267 ft, 4 in. Depth between front and rear brick and masonry walls is 312 ft, 4 in. For low building silhouette and reduced cost, the interior arena is depressed to a depth of 19 ft, 3 in. from grade level, with 7500 permanent seats banked around it and additional room for 4000 temporary bleachers.

Haunches and trusses are of all-welded design, mostly shop fabricated by the International Steel Co., Evansville. Framing for the haunches and truss chords is 14 WF beams ranging from 87 lb per ft to 426 lb per ft, the latter for the vertical haunch members.

Joints are either plain fillets or deep-groove multipass welds in the case of thick sections. Flame shaping and edge beveling preceded welding operations. For fast welding, iron powder electrodes of AWS types E6024 and E6027 were used in combination with a-c current from combination a-c, d-c machines.

Each haunch is pinned at its base with a $6\frac{1}{2}$-in. diam round pin through a hinge plate in the foundation pier. This, along with the $5\frac{1}{2}$-in. pin connecting the truss halves, gives a non-rigid framework which can flex to a degree under snow loads, temperature changes, etc.

Trusses were welded flat in the shop, top and bottom chord beams being connected by verticals and diagonals comprising two 5- x 5- x $\frac{7}{16}$-in. angles welded back-to-back and then to gusset plates inside the beam flanges. Each half truss was shipped in two sections, splice welded in the field, hoisted to position by crane, bolted temporarily to the haunch, pinned to its mating half and finally welded at the haunch connections.

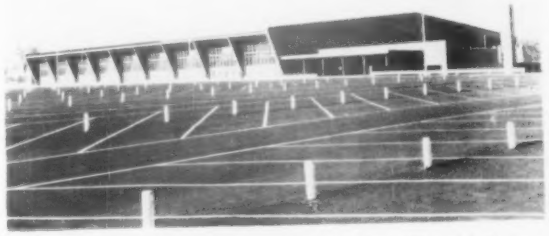

Fig. 1 Sports center at Evansville, Ind., has all-welded structural framework of 80-ton trusses

Fig. 2 First of eight arched and center-pinned trusses is erected. Trusses rest on 14-ton triangular haunches

Based on a story by the Lincoln Electric Co., Cleveland, Ohio.

CHOOSE THE BEST CURRENT FOR TUNGSTEN-ARC WELDING

You know from your daily work that inert-gas-shielded tungsten-arc welding provides speed, quality and economy. But to obtain the best results on each job, you need to operate under the proper welding conditions. For instance, do you know which type of welding current to use for each particular application?

There are three types of current you can use: alternating current high frequency (ACHF), direct current straight polarity (DCSP) and direct current reverse polarity (DCRP).

Alternating current, with superimposed high frequency for better arc stability, can be obtained from a welding transformer. You can obtain direct current from either a rectifier or a motor-generator unit.

A Guide to Success

Table 1 gives you a guide for the type of current to use for different thicknesses and types of metals.

Generally, ACHF is best for tungsten-arc welding of magnesium, magnesium castings, aluminum and aluminum castings, while DCSP is best for tungsten-arc hard-surfacing, and welding of stainless steel, brass alloys, silicon copper, deoxidized copper, silver, Hastelloy alloys, cast iron and both low and high carbon steels. Although you can obtain good results with DCRP when welding magnesium castings, magnesium up to $\frac{1}{8}$ in. thick, and aluminum up to $\frac{1}{16}$ in. thick, DCRP is not usually recommended due to excessive electrode heating.

What About Penetration?

In addition to the thicknesses and types of metals, however, weld penetration is an important factor to consider when choosing the type of current for a particular job. For instance, you obtain deep, narrow weld penetration with DCSP, while DCRP produces a shallow but wider weld bead.

Weld penetration with ACHF is about half way between results obtained with the two types of direct current. The diagram in Fig. 2 compares the weld contours produced with each of the three types of welding current.

Based on a story by the Linde Co., New York, N. Y.

Table 1

Material	*Alternating current* with high-frequency stabilization*	*Direct current — Straight polarity*	*Direct current — Reverse polarity*
Magnesium up to $\frac{1}{8}$ in. thick	1	N.R.	2
Magnesium above $\frac{1}{8}$ in. thick	1	N.R.	N.R.
Magnesium castings	1	N.R.	2
Aluminum up to $\frac{1}{16}$ in. thick	1	N.R.	2
Aluminum over $\frac{1}{16}$ in. thick	1	N.R.	N.R.
Aluminum Castings	1	N.R.	N.R.
Stainless steel	2	1	N.R.
Brass alloys	2	1	N.R.
Silicon copper	N.R.	1	N.R.
Silver	2	1	N.R.
Hastelloy alloys	2	1	N.R.
Silver Cladding	1	N.R.	N.R.
Hard-surfacing	1	1	N.R.
Cast iron	2	1	N.R.
Low-carbon steel, 0.015 to 0.030 in.	2†	1	N.R.
Low-carbon steel, 0.030 to 0.125 in.	N.R.	1	N.R.
High-carbon steel, 0.015 to 0.030 in.	2	1	N.R.
High-carbon steel, 0.030 in. and up	2	1	N.R.
Deoxidized copper‡	N.R.	1	N.R.

KEY: 1. Excellent operation. 2. Good Operation. N.R. Not recommended.

* Where ac is recommended as a second choice, use about 25% higher current than is recommended for DCSP.

† Do not use ac on tightly jigged part.

‡ Use brazing flux or silicon bronze flux for $\frac{1}{4}$ in. and thicker.

Fig. 1 Corner joint welds on aluminum machine covers are made quickly and easily, using a tungsten-arc welding torch at a current setting of 75 amp ACHF

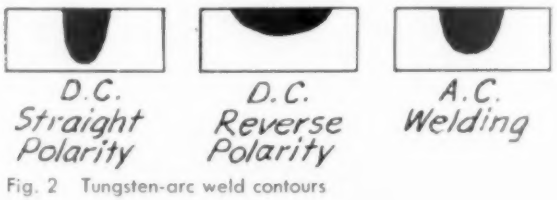

Fig. 2 Tungsten-arc weld contours

WELDING SOLVES CONSTRUCTION PROBLEMS

Allied Construction Services, Inc., Des Moines, Iowa, found a solution to a problem that could well be used by other building contractors.

Specifications for a new school building called for a steel roof deck on steel joists and a composition acoustical block ceiling. The blocks are glued to plaster board or some other sheathing material. How to nail the sheathing material to steel joists was the problem.

Based on a story by Hobart Brothers Co., Troy, Ohio

Here, in Figs. 1 to 4, is how welding solved this problem.

The steel joists were marked off and (steel nailing channel) were welded perpendicular to the joists on 2-ft centers (Fig. 1). A close-up of welder making tack weld to join nailing channel to steel joists is shown in Fig. 2. In Fig. 3, carpenters are nailing plaster board to steel nailing channel; while in Fig. 4, acoustical blocks are being glued to plaster board.

Here, a difficult job was made simple by arc welding. Any other method of fastening the sheathing to metal would have been costlier and more time consuming.

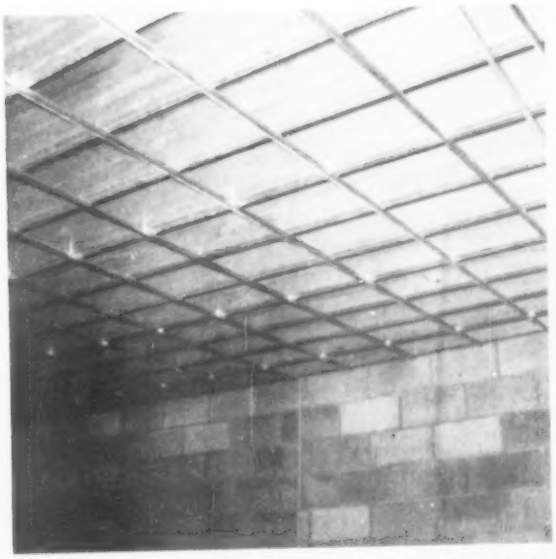

Fig. 1 Steel nailing channels welded perpendicular to the joists on 2-ft centers

Fig. 2 Close-up of welder making tack weld to join nailing channel to steel joists

Fig. 3 Carpenters nailing plaster board to steel nailing channel

Fig. 4 Acoustical blocks being glued to plaster board

Society News

Sixth Annual Welding Show To Break All Previous Records

The Sixth Annual Welding Show will be held in St. Louis on Tuesday through Thursday, April 15th through the 17th. The Kiel Auditorium will be the specific site for the show and, as such, is expected to break all previous records for size of exhibition area. The 1958 event will use 33,664 sq ft of area, an increase over the 32,910 sq ft at last year's show in Philadelphia. Approximately 125 companies will participate in the demonstration and exhibition of their products.

The choice of St. Louis, the eighth largest city in the country, provides a geographical location accessible from all industrial areas within the United States. Past shows have been held in Houston, Buffalo, Kansas City, Buffalo again and Philadelphia.

During the same week, April 14-18 inclusive, the SOCIETY will hold its annual technical meeting at the Hotel Statler, where 21 sessions will be held—17 to be sponsored by AWS and 4 under the sponsorship of the ASME Metals Engineering Division.

The 1958 Adams Lecture will be delivered by Dr. Ernest F. Nippes, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y. The title of Dr. Nippes' proposed lecture will be "The Weld Heat-Affected Zone."

Included in the over-all program will be the customary President's Reception at the Hotel Statler to be followed by a dinner under the sponsorship of the St. Louis Section.

An indication of the expected magnitude of the show is revealed by the fact that virtually the entire space available to exhibitors was disposed of immediately after the first announcement. A sellout of hotel rooms is similarly anticipated.

The St. Louis Kiel Auditorium is on Market Street, fronting on Memorial Plaza, in the heart of the busy city. The exhibition hall for the AWS April Show is located on the ground floor.

Goehringer Nominated District #2 Director

Ernest E. Goehringer has been nominated Director of District #2 of the AMERICAN WELDING SOCIETY for the 1958-60 term. Mr. Goehringer is currently district engineer for the Lincoln Electric Co. in Springfield, Pa., near Philadelphia.

He graduated from Ohio State University in 1935 with a bachelor's degree in Electrical Engineering and joined the Lincoln Electric Co. immediately after graduation. He was a member of the engineering department until 1937 when he was transferred to the sales department in New England. Mr. Goehringer was sent to Philadelphia in 1940 where he remained until 1949. During this period he also served as consultant to the U. S. Maritime Commission, instructed inspectors for the Ordnance Department and taught evening courses in welding engineering at Drexel Institute of Technology. Mr. Goehringer was sent by Lincoln to their Indianapolis office in 1949 where he was active in the Indiana Section. He returned to Philadelphia in 1952 and became chairman of the Philadelphia Section during the 1955-56 term.

Listed among his achievements with the SOCIETY are chairman of the arrangements committee at the AWS National Fall Meeting in 1955 at Philadelphia; chairman in 1955 of the District #2 Nominating Committee; member of the arrangements committee at the AWS National Spring Meeting in 1957 at Philadelphia; and member of the 1957 National Nominating Committee.

Kreidler Nominated

Carl L. Kreidler, Lehigh Structural Steel Co., Allentown, Pa., has been nominated to serve as District #2 representative on the AWS National Nominating Committee.

Two New Supporting Companies for AWS

Two new Supporting Company enrollment applications have been received at National Headquarters. They are Dillon Supply Co., 216 S. West St.,

Raleigh, N. C., and Bell Aircraft Corp., P. O. Box 1, Buffalo 5, N. Y. Both enrollments became effective on December 1, 1957.

Cincinnati Milling Machine New Sustaining Member

The Cincinnati Milling Machine Company, Cincinnati 9, Ohio, became a Sustaining Member of the AMERICAN WELDING SOCIETY on July 1, 1957.

The world's largest builder of machine tools, the products of the manufacturer include a complete line of milling, grinding, broaching, cutter sharpening, flame heating, induction heating, metal-forming and metal-spinning machines, cutting fluids and precision grinding wheels. The home office and plants are in Cincinnati; other plants are in Wilmington, Ohio; Birmingham, England and Vlaardingen, Netherlands.

The Sustaining Member representative is W. A. Maddox.

Structural Steel Company Becomes Sustaining Member

Mississippi Valley Structural Steel Co., Melrose Park, Ill., has joined the rapidly expanding group of AWS sustaining members.

MVSS is engaged in the engineering and fabricating of structural steel for buildings, factories, bridges and many different kinds of industrial equipment. The company was founded in 1902 at Decatur, Ill. Today the company is one of the largest independent fabricators of structural steel in the United States, with plants in 6 cities: Decatur, Ill.; St. Louis, Mo.; Melrose Park, Ill.; Flint, Mich.; Chattanooga, Tenn.; and Lansing, Mich.

The Sustaining Member representative is R. L. La Bounty.

November 19, 1957

Dear Member:

During the past few years there has been a feeling within the Board of Directors of the AMERICAN WELDING SOCIETY *that perhaps some change should be made in the classification of memberships in order to satisfy the needs of the various types of members more fully. During this time the problem was referred to a special committee called the Membership Classification Committee. This committee has had many meetings and has conducted opinion polls throughout the section officers of the* SOCIETY. *Many ideas have been considered for membership classification changes but in every case there were almost as many people against such a change as there were for it, and in no case did there seem to be a clear majority favoring any change in our membership classification.*

During these years this committee has considered changing from our present membership gradation to a single membership classification. They have also considered a higher grade of membership intended in some way to recognize technical education or technical ability in welding engineering. They have considered a Junior grade of membership for the young man just coming out of school and going into the welding trade. They have considered some sort of a special membership for welding operators. Many other classifications have been considered but the above are the principal ones and all of these were given much thought and consideration.

In the end it seemed that none of these classifications were demanded by a considerable group of our membership, and consequently it was agreed that no action would be taken to institute any of these changes. It was decided, however, to point out the fact that the Board of Directors stood ready and willing to modify the membership classification of the SOCIETY *in any way that seemed to be necessary to fill the need of any large group within the* SOCIETY. *In other words, if there is a requirement for some change in membership classification and this requirement is evidenced by popular demand, the Board of Directors is anxious to fulfill that demand. If you and your co-members feel the need of some such change please let your wants be known.*

John H. Blankenbuehler
Chairman
Committee on Member Classes

AWS DIRECTORS-AT-LARGE

Term Expires	1958	1959	1960
	F. H. Dill	J. H. Blankenbuehler	J. F. Deffenbaugh
	E. D. Peters	G. E. Linnert	A. E. Pearson
	J. L. Wilson	P. G. Parks	C. M. Styer
	R. J. Yarrow	F. H. Stevenson	R. M. Wilson, Jr.

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District No. 2•Middle Eastern	D. B. Howard	District No. 8•Midwest	F. G. Singleton
District No. 3•North Central	H. E. Miller	District No. 9•Southwest	P. V. Pennybacker
District No. 4•Southeast	E. C. Miller	District No. 10•Western	C. L. Breese
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District No. 6•Central	Keith Sheren		

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Junior Past-President	F. L. Plummer	Junior Past-President	J. J. Chyle

THINGS YOU SHOULD KNOW

(That Happened in November)

● Many outstanding leaders of AWS activities gathered in Chicago early in November for an important series of events including special panel sessions of the Second World Metallurgical Congress, an informal AWS dinner organized by the Chicago Section, meetings of our Member Classes, Finance and Executive Committees, Technical Council and Board of Directors.

● A special AWS committee with your Secretary acting as Chairman cooperated with ASM staff in planning three panel discussions with three foreign and three United States confreres serving on each panel. The three sessions were devoted to discussions of "Welding in Shipbuilding" with Dave Brown as moderator, "Welding Electrodes" with Dr. D. C. Smith as moderator and "Preheating and Stress Relieving" with Leon Bibber as moderator.

● John Blankenbuehler chairmaned a meeting of the Member Classes Committee at which operator, junior, engineer and fellow classes of membership were considered. Read John's statement which appears elsewhere in this issue and then send your comments and suggestions to him or to headquarters.

● At the meeting of the Technical Council with First Vice-President G. O. Hoglund as chairman, TAC Chairman Art Kugler and Technical Secretary Ed Fenton presented a detailed report covering the 40 projects now being actively developed by technical committees. They also described a number of other needed projects on which work must be deferred because of lack of staff in the technical department which has been seeking an assistant technical secretary for several months.

● Almost one hundred national, district and section officers of the SOCIETY attended a dinner held in the new Prudential Building on Chicago's Michigan Avenue. The dinner was planned by the Chicago Section of which H. H. Comstock is Chairman with District Director Al Chouinard furnishing the inspiration.

● Most of your national officers and directors joined President Sander in an important all-day meeting of the Board of Directors held November 7th in Hotel Sherman. At this meeting your directors approved the dates (April) and sites selected by the Exposition Committee for Annual Spring Meetings and Welding Expositions during the next five years: 1958 St. Louis, 1959 Chicago, 1960 Los Angeles, 1961 New York, 1962 Cleveland. They also approved the recommendation of the Headquarters Housing Committee that the SOCIETY accept the invitation to establish its headquarters in the new United Engineering Center in New York. This center, including a modern twenty-story tower adjacent to the United Nations Building, will provide air-conditioned office space together with dining facilities, complete library, display rooms, meeting rooms and many coordinated central facilities. It will be occupied by more than twenty of the major national technical and engineering groups.

● Al Chouinard, chairman of the Section Advisory Committee, reported that the District Directors did not favor any change in the rules governing refunds to Sections, although there was some support for giving larger refunds to new and small sections and decreasing refunds to larger sections.

● The Board decided to hold a national fall meeting in 1959 and authorized the appointment of a committee to determine time, location, program and financing of such a meeting without exposition.

● Following the AWS and ASM meetings, your Secretary remained in Chicago for important committee meetings of the American Petroleum Institute and then joined Assistant Secretary Mooney in St. Louis for a meeting with the local arrangements committee for the April 14-18, 1958 Annual Meeting and Welding Exposition. Peter Enslin is chairman of the St. Louis Section and H. M. Gillerman is chairman of the large group of St. Louis members who will plan and staff many of the important meeting activities, including the Annual Dinner and the Inspection Trips.

● From St. Louis your Secretary journeyed to Washington where he inspected shop and field operations of B and M Welding and Iron Works of which Bernice M. McPherson is President. Following an interesting afternoon with Mr. and Mrs. McPherson we all joined the officers and members of AWS Washington Section for a social hour, dinner and technical meeting at which your Secretary presented a "Coffee talk" devoted to Society activities and later a technical talk about control of distortion for which Ray Stitt had generously furnished slides and techni-

Resolution

Marguerite Mary Kelly

Secretary Emeritus Marguerite Kelly paid a last visit to the AMERICAN WELDING SOCIETY on Thursday afternoon, October 17th. It was her usual courtesy call when she was in the neighborhood. She looked just grand to all of her former associates, and she expressed pleasure at the smooth operation of the SOCIETY. She made it a point to talk and to compare notes with each of her former associates. Early morning, Tuesday, October 22nd she was stricken with another heart attack but this time medical science was no avail and the AMERICAN WELDING SOCIETY lost one of its greatest champions.

Miss Kelly served the SOCIETY since its inception in March 1919. first for one year as assistant secretary, two years as acting secretary and then, until her retirement from active duty in October 1949, as secretary. These were her principal titles—there were many others, as she had an enormous capacity for work. Marguerite Kelly, operating in a man's world as secretary of an engineering society, expected and received the respect and homage due an attractive woman. Her regal demeanor, her Irish wit, her political sagacity, her sense of fair play, her fearlessness, charmed friend and foe, made the welding operator feel at ease in her presence and quieted conflicting demands of rival interests; made the scientist and engineer feel their work counted and gave her fellow workers the satisfaction of knowing they were part of an important team.

Her accomplishments are written in indelible ink in the records of the SOCIETY and are measured by its growth, accomplishments and stability, and in the hearts of the members and staff who played their part in these efforts.

RESOLVED, That this expression of sorrow and great loss in the passing of Marguerite Mary Kelly, a good and dear friend, a loyal and faithful staff officer, a noble woman, be entered in the records of the AMERICAN WELDING SOCIETY, and a copy be sent to her family with an expression of our sincere sympathy at our mutual loss.

eal background. Chairman H. Montaigne conducted the meeting with A. L. Tarr acting as technical moderator and R. E. Metius serving as the second member of a two-man panel during the question period. Mrs. McPherson has the unique distinction of being the only woman who has been chairman of an AWS section. She is a staunch supporter of AWS and has been active not only in the Washington and Baltimore areas but elsewhere throughout the nation.

● On November 19th the American Council of the International Institute of Welding met in New York to hear reports of the thirty representatives who attended the meeting in Essen, Germany last July. The work of IIW continues to expand and it becomes more essential that there be competent and continuing representation of the interests of American industry on the various IIW commissions. It seems probable that AWS will have to supply additional support and leadership in these activities during the next few years. The SOCIETY is represented on the Governing Council of IIW by Past-President Clyde and your Secretary.

● Chairman Roger Clark held an all-day meeting of the committee concerned with qualification of procedures and welders on November 21st. A complete philosophy covering quality control was described in an article published in the September 1957 issue of THE WELDING JOURNAL. Technical committees will now attempt to apply this philosophy to specific codes such as the one covering the construction of buildings. With proper design and inspection, procedure qualification can be completed for any given set of conditions. Then each manufacturer and each welder could demonstrate his ability to follow properly the qualified procedure by workmanship samples taken from production.

● The Handbook Committee with Dr. R. D. Stout as Chairman met on November 26th to consider several important problems. In order to insure that chapter committees for the handbook should be entirely representative, it was decided to ask for suggestions from AWS Section Executive Committees. Each chapter committee should include representatives of the manufacturers of welding equipment, the fabricators who use the equipment and the users of the finished products. Such representatives should be chosen from different companies and geographic locations. The final committees will be selected from the names suggested by the Sections.

● Copies of the first section of the new Welding Handbook were mailed to members with post binder and outer covers. Some covers were damaged in transit. These will be replaced without additional charge to any who report to headquarters that they have received damaged covers. Based on experience to date, the Committee has decided to recommend that the use of loose covers be discontinued and that future sections be provided with flexible or hard covers.

Fred L. Plummer

EAC DOINGS

Welding Training Aids for Your Plant

by Orville T. Barnett*

There are many excellent training programs available for the in-plant training of welding personnel. Some of these have been assembled from manufacturers' literature while others have been gotten together by individual plant welding engineers. Those in-plant training programs that have been reviewed by this Committee have shown an excellence that reflects the ability of those who drew up the program. The programs varied, of course, to suit the specific needs of the plant for which they were prepared.

The "in-plant training program" has been defined as follows: "It shall be the duty of this Committee to write, revise, review or outline texts and programs to promote in-plant training in welding applications." The assignment is broad and challenging. Many dedicated committee members are working hard against fixed deadlines to provide whatever teaching aids are needed.

Under the leadership of Irving Betz of Frankford Arsenal, a tentative outline for an in-plant training course has been developed for designers, inspectors and supervisors. It was felt that enough educational material existed for the training of welders and welding operators and it was further felt that welding technicians might be trained by trade schools. This Committee, therefore, has taken as its objective the teaching of designers, inspectors and supervisors as these people must use welding to best advantage. They represent an area where welding skills and abilities may not be as well integrated into their everyday activities as they should be.

While this outline, which covers some six pages, has been reviewed by the Committee, a number of weak points were revealed subsequently. Suggestions have been made and these suggestions constitute a program of revision. It is hoped that this new outline will be completed very soon and be available through the headquarters of the following major subjects (a detailed breakdown has not been listed):

I Orientation, Welding Terms, Positions, Joint Types and Definitions
II Welding and Allied Processes
  A. Welding
  B. Arc and Gas Cutting and Gouging
  C. Brazing
  D. Surfacing and Metallizing
  E. Soldering
  F. Laboratory Demonstration
III Basic Metallurgy
  A. An Introduction to the Manufacture of Important Weldable Metals
  B. The Structure and States of Aggregation of Metals
  C. The Properties of Metals
  D. Alloying of Metals
  E. Thermal Treatment of Metals
  F. Metallurgy of Welds
IV Weldability of Metals
  A. Ferrous
  B. Nonferrous
  C. Dissimilar Metals
  D. Filler Metals
  E. Laboratory Demonstration and Practice
V Welding Design
  A. Design Considerations for Welding
  B. Welding Symbols and Blue Print Orientation
VI Specifications: Their Construction and Use
  A. Purpose of Specifications
  B. Basic Segments of Specifications
VII Qualification: Welders and Welding Procedures
  A. Purpose of Qualification

* Chairman, Subcommittee on In-Plant Training, AWS Educational Activities Committee; Assistant Manager, Metals Research Department, Armour Research Foundation of Illinois Institute of Technology, Chicago 16, Ill.

B. General Qualification and Requalification Practices

VIII Inspection, Testing and Quality Control
- A. Inspection
- B. Testing Methods
- C. Quality Control
- D. Laboratory Demonstration

IX Safe Practices in Welding

X Review

It may be seen that a most comprehensive program is planned. The idea here is to make available a complete in-plant training text. From this quite comprehensive collection of material each plant could select only those portions that were germane to its operation. In this manner, an in-plant training welding course could be slanted to company requirements using the individual components of the outline that were most essential to their training objectives.

The job of teaching has to be made as simple as possible. For this reason, the In-Plant Training Committee has used a suggested procedure for the preparation of instructional guides that, once again, was altered from government training methods by Mr. Betz to suit welding needs. It covers complete details of presenting the text materials and will form a basis on which uniform lessons can be prepared. It will list all of the things to be done, including the presentation of the subject, visual aids, homework assignments where desirable, and suitable references. Every effort will be made to put these programs together in such form as to enable the AWS to publish the lessons at a modest cost including the related visual aids.

In addition to the procedure for the preparation of instructional guides, there is a sample lesson plan. This gives the complete presentation for one phase of welding subject showing how all of the teaching steps can be used to make certain that the students thoroughly understand the material that is presented.

It is recognized that the plans of the In-Plant Training Committee are quite ambitious. Yet, the outline has been prepared and assignments have been issued for the writing of the text. It is hoped that by early next year a completely acceptable outline will have been approved by the Committee. Then the more difficult task of preparing the specific lessons will take place and this will probably take some considerable period of time, but as each lesson becomes available it will be blocked into place and the outline will be filled in as quickly as is practical.

Since the In-Plant Training Committee of EAC is trying to serve all the members of AWS, the Committee will appreciate any criticism or suggestion that will improve the value of its work to the membership.

Chicago Site for Midwest Welding Conference

The fabrication of a new type of structure used in aircraft and missile construction will be described at the fourth annual Midwest Welding Conference to be held in Chicago on January 29 and 30.

Frank J. Filippi, project liaison engineer, Solar Aircraft Co., San Diego, Calif., will speak on "Fabrication of Brazed Honeycomb Sandwich Panel," at the January 29 afternoon session of the two-day conference sponsored by Armour Research Foundation of Illinois Institute of Technology and the Chicago Section of the AMERICAN WELDING SOCIETY.

The conference will be held in the Illinois Tech Chemistry Building at 3255 S. Dearborn St.

Two other papers to be presented at the afternoon session are "Novel Production Brazing Applications," by A. M. Setapen, manager of the engineering division, Handy and Harman, New York, and "Brittle Fracture" by P. P. Puzak, head of the welding section, U. S. Naval Research Laboratory, Washington, D. C.

Nine additional papers to be given at the conference are:

January 29, morning—"A User Reports on T-1 Steel," by Perry C. Arnold, welding engineer, Chicago Bridge and Iron Co., Chicago; "Design for Welding," by Omer W. Blodgett, design consultant, Lincoln Electric Co., Cleveland, and Jay Bland, head of metals and welding section, engineering research department, Standard Oil Co., Whiting, Ind.

January 30, morning—"Recent Developments in Power Sources for Welding," by Warren Sykes, chief electrical engineer, Miller Electric Manufacturing Co., Appleton, Wis.; "New Techniques in Welding Aluminum," by F. R. Baysinger, head of welding branch, metallurgical research department, Kaiser Aluminum and Chemical Corp., Spokane, Wash., and "Automatic Resistance Welding Applications," by Thomas C. Falter, welding engineer, Frigidaire division, General Motors Corp., Dayton, Ohio.

Afternoon—"Manual Electrodes for Code Governed Weldments," by Amel R. Meyer, chief of welding research, Graver Tank and Manufacturing Co., East Chicago, Ind.; "A New CO_2 Welding Process," by A. F. Chouinard, manager of research and development department, National Cylinder Gas Co., Chicago, and "Nickel Alloy Welding of Dissimilar Alloys by Arc and Inert Gas Processes," by K. M. Spicer, assistant supervisor, mechanical engineering section, International Nickel Co., New York.

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TECHNICAL PAPERS SESSIONS

1958

AWS NATIONAL SPRING MEETING and ASME METALS ENGINEERING DIVISION CONFERENCE

APRIL 14–18 • HOTEL STATLER, ST. LOUIS, MO.

REGISTRATION
HOTEL STATLER

Sunday, April 13
3:00 P.M. to 6:00 P.M.
Monday, April 14
8:00 A.M. to 3:00 P.M.
Tuesday, April 15
8:00 A.M. to 4:00 P.M.
Wednesday, April 16
8:30 A.M. to 4:00 P.M.
Thursday, April 17
8:30 A.M. to 4:00 P.M.
Friday, April 18
8:30 A.M. to 12:30 P.M.

APRIL 14, MONDAY MORNING

Grand Ballroom

10:00 A.M—Official Opening & Business Session

Address—*C. P. Sander, President, AWS*

National Awards

Adams Lecture—*The Weld Heat-Affected Zone*
by Ernest F. Nippes, Rensselaer Polytechnic Institute

APRIL 14, MONDAY AFTERNOON—THREE SIMULTANEOUS SESSIONS—2:00 P.M.

1. Steel Weldability and Research

Grand Ballroom

A. The Effects of Porosity on Mild-Steel Welds
by William L. Green and Roy B. McCauley, Ohio State University

B. Effect of Steel Deoxidation Practice on Submerged-Arc Weld Porosity
by James T. Lapsley, Jr., University of California, Berkeley

C. A Study of Factors Affecting the Strength and Ductility of Weld Metal
by C. Martin Wayman, University of Illinois, and Robert D. Stout, Lehigh University

2. Designing for Welding

Missouri Room

A. Elements of Joint Welding for Design
by Kenneth H. Koopman, Knolls Atomic Power Lab., General Electric Co.

B. A Simplified Approach to Determining Stresses and Selecting Sections
by Omer Blodgett, The Lincoln Electric Co.

C. Product Design for Welding
by John Mikulak, Worthington Corp.

3. Welding Arcs and Heat Flow

St. Louis Room

A. Some Practical Limitations of High-Current Arcs
by A. Lesnewich, Air Reduction Research Laboratory

B. Plasma Energy Transfer in Gas-Shielded Welding Arcs
by H. C. Ludwig, Westinghouse Research Laboratories

C. Cooling Rates and Peak Temperatures in Fusion Welding
by Clyde M. Adams, Jr., Massachusetts Institute of Technology

APRIL 15, TUESDAY MORNING—THREE SIMULTANEOUS SESSIONS—9:30 A.M.

4. Strength of Welds
Grand Ballroom

This session is sponsored by the ASME Metals Engineering Division

A. Co-operative Investigation of a New Welding Electrode for Stainless Steels

by R. D. Wylie, The Babcock & Wilcox Co.

B. The Welding of Cr-Mo-V Steels for High-Temperature Service

by R. J. Christoffel, R. M. Curran, F. H. Domina and C. H. Soldan, General Electric Co.

C. Welding Qualifications and Component Performance

by W. L. Fleischmann, Knolls Atomic Power Laboratory, General Electric Co.

5. Resistance Welding
St. Louis Room

A. Spot Welding of Inconel X in Thickness Range of 0.032 to 0.188

by Jean F. Harris, J. J. Riley, The Taylor Winfield Corp., and M. D. Bellware, International Nickel Co.

B. Spot Welding of Ti-6Al-4V Alloy

by Robert K. Nolen, John F. Rudy and Harry Schwartzbart, Armour Research Foundation, and H. D. Kessler, Titanium Metals Corporation of America

C. Evaluation of Spot Welds Made Through Primers and Sealers

by B. A. Schero, Detroit Arsenal

6. Aluminum and Magnesium
Rooms 202–204

A. Porosity in Aluminum-Alloy Welds

by Fred R. Collins, Alcoa Research Laboratories

B. New Forge Welding for High-Strength Aluminum and Magnesium Alloys

by Lloyd A. Cook and Donald G. Shafer, Ravens Metal Products, Inc.

C. Arc Welding of Wrought Magnesium-Thorium Alloys

by Paul Klain, The Dow Chemical Co.

APRIL 15, TUESDAY AFTERNOON—THREE SIMULTANEOUS SESSIONS—2:00 P.M.

7. Mating of Structural Properties with Design
Grand Ballroom

This session is sponsored by the ASME Metals Engineering Division

A. Design Values for Thermal Stress in Ductile Materials

by B. F. Langer, Westinghouse Electric Corp.

B. Design of Thin-Walled Pressure Vessels Based Upon the Plastic Range

by M. G. Sharma and Joseph Marin, Pennsylvania State University

C. Ductility and Energy Relations in Charpy Tests of Structural Steels

by J. H. Gross and R. D. Stout, Lehigh University

8. Resistance Welding
St. Louis Room

A. An Investigation of Lap Seam Welds in 17-7PH Stainless Steel

by E. J. Funk and A. C. Willis, Temco Aircraft Corp.

B. The Resistance Seam Welding of Galvanized Steel

by M. L. Begeman, The University of Texas and William J. Allen, Shell Development Co.

C. Frequency Converter Welding Control Using Counting Tubes

by L. R. Broniak and W. Chaisson, Weltronic Company

9. Titanium
Missouri Room

A. Technique for Metal-Arc Welding Titanium

by Bruce L. Baird and Robert P. Olsen, North American Aviation Co.

B. Inert-Gas Welding of Titanium for Nuclear and Chemical Application

by G. M. Adamson, Jr., and W. J. Leonard, Union Carbide Nuclear Co.

C. Development of Titanium-Clad Steel Using a Vacuum-Brazing Process

by Domenic A. Canonico and Harry Schwartzbart, Armour Research Foundation

APRIL 16, WEDNESDAY MORNING—THREE SIMULTANEOUS SESSIONS—9:30 A.M.

10. Design and Material for Low Temperature Application

Grand Ballroom

This session is sponsored by the ASME Metals Engineering Division

A. The Effect of Heat Treatment on the Microstructure and Low Temperature Properties of Pressure Vessel Steels

by J. H. Gross, E. H. Kottcamp and B. D. Stout, Lehigh University

B. Some Results of Fatigue and Welding Tests of 9 Percent Nickel Steel Plate

by T. N. Armstrong, International Nickel Co., and J. H. Gross, Lehigh University

C. Pressure Equipment for Low Temperature Service

by C. R. Soderberg, Jr., M. W. Kellogg Co.

11. Brazing

St. Louis Room

A. Proposed Procedure for Testing Shear Strength of Brazed Joints

by Forbes M. Miller and Robert L. Peaslee, Wall Colmonoy Corp.

B. Diffusion Bonding Below 1000 F

by J. T. Niemann, B. P. Sopher and P. J. Rieppel, Battelle Memorial Institute

C. Bonding of Cermet Valve Components to Metals

by Gerald M. Slaughter, P. Patriarca and W. D. Manly, Oak Ridge National Laboratory

12. Uranium, Titanium and High-Nickel Alloys

Missouri Room

A. Submerged-Arc Welding of Uranium

by Gale S. Hanks, J. M. Taub and E. L. Brundige, University of California

B. Cracking Associated with Porosity in Titanium Welds Over 0.125 in. Thick

by Robert P. Olsen and James Gates, North American Aviation Co.

C. Control of Porosity in High-Nickel Alloy Welds

by George B. Pease, Robert E. Brien and Pierre E. LeGrand, International Nickel Co.

APRIL 16, WEDNESDAY AFTERNOON—THREE SIMULTANEOUS SESSIONS—2:00 P.M.

13. Steel Weldability and Research

Kiel Auditorium—Assembly Hall No. 1

A. Evaluation of Weld Joint Flaws as Reinitiating Points of Brittle Fracture—Part II

by Raeman P. Sopher, Perry J. Rieppel, David C. Martin, Battelle Memorial Institute, and Arthur L. Lowe, Jr., The Babcock and Wilcox Co.

B. Dynamic Measurement of Stress Associated with Weld Cracking

by Clyde M. Adams, Jr., Sheldon S. White and William G. Moffatt, Massachusetts Institute of Technology

C. Energy Absorption Studies of Welds in Tempered Martensitic Base Metal

by W. H. Bruckner, University of Illinois, and C. A. Robertson, Sun Oil Co.

14. Brazing

Kiel Auditorium—Assembly Hall No. 2

A. The Metallurgy of Bonding in Brazed Joints

by Nikolajs Bredzs, Armour Research Foundation

B. Fundamentals of Brazing for Elevated-Temperature Service

by M. D. Bellware, International Nickel Co.

C. High-Temperature Vacuum Brazing of Jet-Engine Materials

by Ernst G. Huschke, Jr., and George S. Hoppin III, General Electric Co.

15. Welded Structures

Kiel Auditorium—Assembly Hall No. 3

A. The Design and Fabrication by Welding of the Carquinez Strait Bridge

by Leonard C. Hollister, California Division of Highways

B. Design of a Large-Span Grid Roof

by Wayne Teng, Skidmore, Owens & Merrill

C. Behavior of Welded Corner Connections

by John W. Fisher, George C. Driscoll, Jr., Lehigh University, and F. W. Schutz, Georgia Institute of Technology

APRIL 17, THURSDAY MORNING—THREE SIMULTANEOUS SESSIONS—9:30 A.M.

16. Casting Weldments
Grand Ballroom

This session is sponsored by the ASME Metals Engineering Division

A. Casting Weldments in a Petroleum Refinery
by Jay Bland, C. B. Parrish and R. C. Wheeler, Standard Oil Co.

B. The Welding of Low Alloy Steel Castings Designed for High-Temperature, High-Pressure Service
by N. A. Chapin, C. H. Soldan and L. W. Songer, General Electric Co.

C. Procedure for Production of Cast Weldments and Weld Repair of Castings for Nuclear Service
by W. N. Rice, Electric Steel Foundry Co.

17. Steel Weldability and Research
Missouri Room

A. A Theory for Preheating of Plain, Low-Carbon Steels
by E. Paul DeGarmo, University of California, Berkeley

B. Temperatures for Rapid Uniaxial Stress Relief of Stainless Steels
by Howard S. Avery, American Brake Shoe Co.

C. A Quantitative Evaluation of Residual Stress Relief in Pipe Weldments
by Jack E. Cook, General Motors Institute, and Roy B. McCauley, Ohio State University

18. Gas-Shielded Welding
St. Louis Room

A. Case Studies: Industrial Use of Manual Magnetic-Flux Gas-Shielded Arc Welding
by R. T. Telford, Linde Co.

B. Controlled-Atmosphere Arc Welding
by Norman E. Weare and Robert E. Monroe, Battelle Memorial Institute

C. Tungsten-Arc Welding of 0.002, 0.005 and 0.008 Stainless Steel and Titanium
by J. C. Collins and S. P. Jenkins, Convair

APRIL 18, FRIDAY MORNING—THREE SIMULTANEOUS SESSIONS—9:30 A.M.

19. Submerged Arc Welding
Grand Ballroom

A. Welding Alloy Steels Under Bonded Fluxes
by Hallock C. Campbell and Wallace C. Johnson, Arcos Corp.

B. Submerged-Arc Alloying for Maintenance and Fabrication
by Robert A. Wilson, The Lincoln Electric Co.

C. Submerged Arc Applications in the Fabrication of Railroad Car Components
by Charles A. Zwissler, Kaiser Steel Corp., and Robert A. Hay, Linde Co.

20. Application, Equipment and Inspection
Missouri Room

A. Automatic Welding of Small Aircraft Accessory Turbine Wheels
by Allan J. Rosenberg and Ernest W. Jamison, General Electric Co.

B. Aluminum Welding Cable
by John G. Slone, Kaiser Aluminum & Chemical Corp.

C. Use of Radioactive Welding Wire as a Means of Nondestructive Inspection of Welds
by Paul T. Barnes, U. S. Naval Ordnance Test Station, and Gordon L. Locher, Western Radiation Laboratory

21. Gas-Shielded Welding
St. Louis Room

A. Inert-Gas-Shielded Consumable-Electrode Welding of Molybdenum
by Norman E. Weare, Robert E. Monroe and David C. Martin, Battelle Memorial Institute

B. Inert-Gas-Shielded Arc Welding of Silicon and Aluminum Bronzes
by Paul L. Hemmes, Revere Copper and Brass Inc.

C. Effect of Welding Speed on Strength of 6061-T4 Aluminum Joints
by William L. Burch, Bell Aircraft Corp.

The above schedule of technical papers is not necessarily final. A more complete and detailed program, including an account of other activities, will be published in the April issue of THE WELDING JOURNAL.

WELDING SHOW EXHIBITS AND DEMONSTRATIONS
KIEL AUDITORIUM

Hours of the Exposition

Tuesday, April 15
12:00 Noon to 10:00 P.M.
Wednesday, April 16
10:00 A.M. to 10:00 P.M.
Thursday, April 17
10:00 A.M. to 6:00 P.M.

Admission by Registration

Section News and Events

as reported to Catherine O'Leary

TECHNICAL BULLETIN

Phoenix, Ariz.—The third regular meeting of the season for the *Arizona* Section was held at the Sahara Hotel Sky Room at 7:30 P.M. on Wednesday, November 20th. Twenty-four members and guests were present including four students from Phoenix Tech. and Arizona State College.

Two sound color movies were shown through the courtesy of the Air Reduction Co. They were: "Whatever We Do" and "Nothing But The Best."

Technical Chairman Phil Binkley gave a short talk on the technical bulletins available.

WELDED STRUCTURES

Bridgeport, Conn. The *Bridgeport* Section met on November 21st in the General Electric Auditorium with Van Rensselaer P. Saxe (M), of Baltimore, Md., as guest speaker.

Mr. Saxe's topic was "Welded Structures" covering such phases as general design, simplicity and economy, safety, practicability and speed of fabrication, and erection. He used colored slides showing outstanding examples of welded structures in connection with his talk. Literature on the subject was distributed to those in attendance.

Over 125 people attended the technical session which was very well received by all the members and guests. In addition to AWS members, invitations were sent to the structural-steel people in Connecticut as well as structural-steel designers and the building inspectors. The principle speaker was introduced by Program Chairman Robert J. Hirsch.

Prior to the meeting, a dinner was served at the Fairways Restaurant in Bridgeport.

ARC SPOT WELDING

Raleigh, N. C.—On October 28th, the regular meeting of the *Carolina* Section was held in the Colonial Room of the S & W cafeteria, starting with dinner at 6:30 P.M.

Guest speaker at the meeting which followed was Edward F. Davis (M), of the Westinghouse Corp., who gave an excellent talk on "Inert-Gas Consumable-Electrode Spot Welding" which was illustrated with slides. A lively discussion period followed.

WELDING METALLURGY

Raleigh, N. C.—The regular monthly meeting of the *Carolina* Section was held in Raleigh, November 25th. The guest speaker for the session was Dr. William Austin, Head of Mineral Industries at North Carolina State College. Dr. Austin's subject was "Metals—What You Should Know About Them When Welding." Highlighting his most interesting speech were: transformation of properties and characteristics of iron and steel during the periods of rising temperatures; cooling and stress relieving; the hardening of high-carbon steel and what may be learned from microscopic inspection of metals.

Dr. Austin also stressed the increasing demand for metallurgists in industry and emphasized the fact that any worthy student interested in entering this field may be helped through scholarships, loans, etc.

RESISTANCE WELDING

Chicago, Ill.—Speaker at the November 15th dinner meeting of the *Chicago* Section was Wallace Rudd of the New Rochelle Tool Co., New Rochelle, N. Y.

His subject, "High-Frequency Resistance Welding," covered methods and processes using 450,000 cycle power for welding tubing, strip steel,

SPEAKS ON STAINLESS STEELS

R. D. Thomas, Jr. discussed the various approaches and methods that can be used in solving problems in stainless-steel welding at the Oct. 18, 1957 meeting of the Chicago Section

SPEAKERS AT CLEVELAND SECTION MEETING

Three of the panel speakers at the October 9th meeting of the Cleveland Section were (*left to right*) Jerry Hinkel, Tom Dempsey and Ed Kerr. O. H. Kuhlke was the fourth speaker. They discussed the question "Which is Better, AC or DC?"

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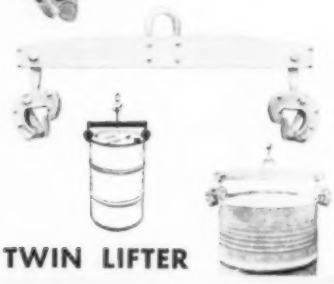

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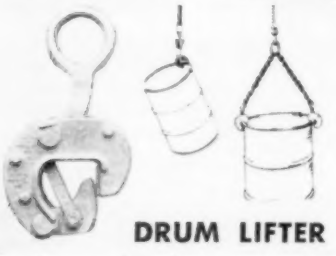

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SECTION MEETING CALENDAR

FEBRUARY 3

LEHIGH VALLEY Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Walp's Restaurant, Allentown, Pa. "Maintenance Welding," Cares Keyser, Bethlehem Steel Co.

FEBRUARY 7

NORTH CENTRAL OHIO Section. Marion. "Nondestructive Testing of Welds," C. E. Betz.

PHILADELPHIA Section. 7:45 P.M. Engineers Club. Panel discussion "Welding of Dissimilar Metals and Alloys."

FEBRUARY 10

NORTHWEST SECTION. Elks Club, Minneapolis, Minn. Happy Half Hour 6:00 to 6:30 P.M. Dinner 6:30 P.M. "Automatic Welding and Positioning," I. R. Bartter, Automatic Welding Co.

FEBRUARY 11

NEW YORK Section. Victor's Restaurant, 1 E. 35 St., N.Y.C. Get-together 5:30 P.M. Dinner 6:00 P.M. Program 7:00 P.M. "Job Shop Operation," Irwin Feiner, P. Feiner & Sons.

WESTERN MASSACHUSETTS Section. Blake's Restaurant, Springfield, Mass. Dinner 6:30 P.M. Meeting 7:30 P.M. "Ultrasonic Inspection of Materials and Weldments," John E. Bobbin, Sperry Products, Inc.

FEBRUARY 12

CLEVELAND Section. Manger Hotel. Social Hour 6:00 P.M. Dinner 6:30 P.M. Meeting 8:00 P.M. "Joining of Dissimilar Metals."

STARK CENTRAL Section. Plant Visit—Griscom Russell Co.

FEBRUARY 13

KANSAS CITY Section. "Metallurgy."

MADISON Section. Eagles Club, Madison, Wis. "Modern Applications of Inert-Gas-Shielded Tungsten-Arc Welding," Harry A. Huff, Air Reduction Sales Co.

FEBRUARY 14

DETROIT Section. 8:00 P.M. Engineering Society of Detroit. "Arc Welding Electrodes," E. B. Lutes, Arcrods Corp.

FEBRUARY 17

PHILADELPHIA Section. Engineers Club. 8:00 P.M. "Why So Many Welding Electrodes," Orville Barnett, Armour Research Foundation.

FEBRUARY 18

HARTFORD Section. Villa Maria Hotel, Glastonbury, Conn. "Design and Brazing of Jet Engine Components for High-Temperature Service," by R. L. Peaslee, Wall-Colmonoy Corp.

NORTHWESTERN PENNSYLVANIA Section. Erie, Pa. "Welding T-1 Steel."

TOLEDO Section. Maumee River Yacht Club. Dinner 6:30 P.M. Meeting 8:00 P.M. "Low-Chrome Alloy Welding."

FEBRUARY 19

PEORIA Section. Mecca Supper Club, Farmington Road, Peoria, Ill. "Natural Gas and Propane Flame Cutting of Steel," John R. Kelly, Pres., Harris Calorific Co.

PITTSBURGH Section. 8:00 P.M. Auditorium of Mellon Institute of Industrial Research (Oakland) Pittsburgh, Pa. "What Welding Process Should I Use?" Joseph Cooper, The Taylor Winfield Corp., M. L. Powers, Linde Co., W. B. Brubaker, Air Reduction Sales Co., C. W. Lytton, Lincoln Electric Co.

PROVIDENCE Section. Dinner meeting 6:15 P.M. Johnson's Hummocks, Providence, R. I. "Inert-Gas Welding," R. W. Tuthill, General Electric Co.

FEBRUARY 20

BRIDGEPORT Section. "Aircraft Welding," D. F. Zimmerman, AVCO Manufacturing Corp.

IOWA Section. Kirkwood Hotel, Des Moines, Iowa. Social Half Hour 6:30 P.M. Dinner 7:00 P.M. Program 8:00 P.M. "Pipe Welding," L. J. Cunningham, Northern Natural Gas Co.

FEBRUARY 21

MARYLAND Section. Joint meeting with local chapter of Society of Non-Destructive Testing. "Nondestructive Testing Methods," Paul Edmiston, Army Chemical Corp.

MILWAUKEE Section. Ambassador Hotel. 6:30 P.M. "Application of Submerged-Arc Welding," Amel R. Meyer, Graver Tank & Mfg. Co.

FEBRUARY 22

SAGINAW VALLEY Section. Saginaw, Mich. Dinner Dance.

FEBRUARY 27

NIAGARA FRONTIER Section. Continental Inn, Delaware Ave., Kenmore, N. Y. Dinner 6:45 P.M. Meeting 8:15 P.M. "Stainless-Steel Welding," R. K. Lee, Alloy Rods.

FEBRUARY 28

INDIANA Section. Indianapolis, Ind. 6:30 P.M. Technical Session and Dinner. "Ultrasonic Welding," W. C. Potthoff, Aeroprojects, Inc.

SAGINAW VALLEY Section. Annual Dinner Dance Party. Hi-Life Inn, Saginaw, Mich. 7:00 P.M.

Editor's Note. Notices for April 1958 meetings must reach Journal office prior to February 1, so that they may be published in March Calendar. Give full information concerning time, place, topic and speaker for each meeting.

LEE ADDRESSES CLEVELAND SECTION

Richard K. Lee spoke on iron-powder low-hydrogen electrodes at the November 13th meeting of Cleveland Section. He is shown above between Section Chairman Bill Mayer (*left*) and Technical Chairman Bill Weber

Approximately 100 members and guests attended the meeting. Enjoying themselves are (*left to right*) Fred Winger, Dave Champion and Bernie Smolka

finned tubing and welding of dissimilar metals.

Some of the cable fabricating processes, wherein an aluminum sheath or tube is formed and welded around a group of wires at fabulous rates of speed, were among the outstanding welding processes discussed.

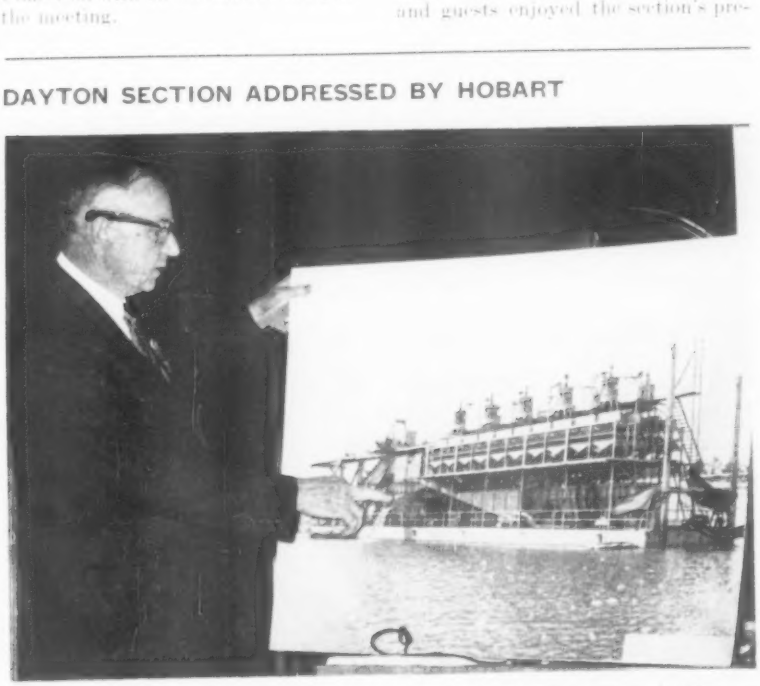
The meeting was held in the auditorium of the Peoples Gas Light & Coke Co., with an attendance of 92 at the meeting.

LOW-HYDROGEN ELECTRODES

Cleveland, Ohio—The second regular meeting of the season of the *Cleveland* Section, November 13th at the Hotel Manger, maintained the same level of attendance and interest shown at open panel-type meetings. Approximately 100 members and guests enjoyed the section's pre-meeting hospitality hour, dinner and technical session. The section-sponsored hospitality hour has proven to be not only a good drawing card but also an effective mixer.

The speaker for the evening was Richard K. Lee [M'45], technical director and vice-president of Alloy Rods. His subject, which he covered interestingly and thoroughly, was "Those Fabulous Iron-Powder Low Hydrogen Electrodes." He outlined the history of the development, giving the main reasons for the designers' conception. He described their performance characteristics and their uses in industry and construction.

DAYTON SECTION ADDRESSED BY HOBART



E. A. Hobart spoke on mining rutile for welding electrode coatings at the November meeting of the Dayton Section. He is shown here pointing to some of the features of a 500,000-lb floating sand separator that was designed and built in Troy, Ohio by Mr. Hobart and shipped to Florida on twenty flat cars

MAGNETIC-FLUX WELDING

Denver, Colo.—The November meeting of the *Colorado* Section was held in a private room of the El Rio Grande Cafe on November 5th. There were 51 members and guests present. Norman Davis [M'52], of the Linde Co. gave an illuminating talk on the subject of "Magnetic-Flux Gas-Shielded Arc Welding." A great deal of interest was shown in the subject as evidenced by the number of questions asked. The talk was illustrated by slides showing the principle of operation and actual applications.

MINING OF RUTILE

Kettering, Ohio—Thirty-five members of the *Dayton* Section enjoyed a delicious turkey dinner, with all the trimmings, on November 12th at the Delco Products Lodge in Kettering.

Forty-eight members attended the regular meeting which was opened with a film describing the manufacture of prestressed concrete water pipe.

Technical speaker was E. A. Hobart [M'52], president of Hobart Brothers Co., Troy, Ohio, who gave a very interesting talk on the "Mining of Rutile for Welding Electrode Coatings." Mr. Hobart related the story of how the Hobart company became interested in mining operations that started a whole new industry in Florida. Hobart, in an effort to improve constantly the quality of arc-welding electrodes, extended their research to the mining of basic minerals that are important in the manufacturing of arc-welding electrodes. This led to the discovery of rutile deposits in the Florida area that were found to be of a much higher grade than imported minerals. Having their own source for a pure grade of rutile not only improves the quality of electrode coatings, but also gives the company complete control over the entire manufacturing cycle. The mining operation is located in the Indian River

County between Vero Beach and Winter Beach, and is known as the Florida Minerals Co. Here, four rare minerals are extracted and separated for commercial use. Important to the company, is rutile or (TiO_2) used as an electrode coating that stabilizes the arc, makes a good metal transfer and gives a shielding slag. Ilmenite, $FeTiO_3$, is a combination of iron oxygen and titanium used largely by the paint industry for making white paint. Zircon, $ZrSiO_4$, is used as a refractory material in furnaces and is also used for enamels. From zircon and rutile, synthetic diamonds can be made. Monozite, a very heavy sand containing 17 different rare earths, contains the important radioactive mineral known as thorium. It is the sister-metal to uranium and since it is more plentiful, will probably be the atomic fuel of the future. All these minerals are found along an ancient shore line which is a ridge about two or three miles west of the present ocean shore. Color slides were used by Mr. Hobart to show the complete mining operation.

METALLIZING

Essex, Conn.—The *Hartford* Section met on November 19th at the Griswold Inn in Essex where a full-course turkey dinner was served prior to the meeting.

A 30-minute movie on "Metallizing. Its Uses and Applications" was shown prior to a talk on the same subject by C. J. O'Boyle, of the Metallizing Engineering Co., Westbury, N. Y. Mr. O'Boyle spoke briefly on new processes not covered in the movie, and then the meeting was thrown open for a question-and-answer period.

POSITION WELDING

Houston, Tex.—Anthony K. Pandjiris (M), president of Pandjiris Weldment Co., St. Louis, Mo., was the guest speaker at the November 20th meeting of the *Houston* Section held at the Ben Milam Hotel. His subject was entitled "Position All Three—The Man, The Work, and The Automatic Head."

A résumé of Mr. Pandjiris' presentation covers five steps which are taken into consideration to improve a particular welding process, namely: (1) the welding operator; (2) product to be welded; (3) welding equipment; (4) assisting devices such as positioners; and (5) work deployment.

There are some thirty-five (35) companies manufacturing approximately $90,000,000 worth of assisting devices yearly. The welding positioners vary from handling items

SPEAKS ON AUTOMATIC WELDING

Anthony K. Pandjiris was the principal speaker at the November 20, 1957 meeting of the Houston Section

weighing 10 lb to 150,000 lb each. Some positioners weigh as much as 100,000 lb.

Many slides were used to illustrate the different kinds of positioners which handled anything from small parts to railroad cars and heavy submarine parts.

The subject was very interesting and the demonstration proved Mr. Pandjiris to be a top expert in the welding positioner field.

Roy Pringle, the Houston Section chairman, gave a report on welding progress up to date, stating that for 1957 it is expected to reach the billion dollar mark.

Larry Megow requested that the welding engineers give cooperation to a junior high school boy's organization named "Jets." "Jets" encourage young boys to pursue engineering as a career.

INDUCTION HEATING

Cumberland, Ind.—The November dinner meeting of the *Indiana* Section was held on November 22nd at Buckley's Restaurant where a very interesting talk on "Induction Heating" was given by William F. Peschel, application engineer for the Ohio Crankshaft Co. (TOCCO), Cleveland, Ohio.

RESISTANCE WELDING

Des Moines, Iowa—The regular monthly meeting of the *Iowa* Section was held in the Garden Room of the Kirkwood Hotel on November 21st with 55 members and guests at the dinner and meeting.

G. E. Kuhr (M), membership chairman, announced the start of a membership campaign from Nov. 21, 1957 to Feb. 20, 1958. At the end of the campaign a radio will be given away to the lucky winner.

The technical meeting was turned over to the speaker J. H. Cooper (M), chief sales engineer for the Taylor Winfield Corp. His subject "Special Resistance Welding Application" was illustrated by movies showing how resistance welding can be applied to the high production of automotive and refrigeration industry. His subject was very interesting and appreciated by the audience.

GAS CUTTING

Allentown, Pa.—The *Lehigh Valley* Section met on November 4th for dinner and meeting at Walps Restaurant in Allentown.

The feature of the dinner program was the showing of color movies by Mr. and Mrs. H. O. Hill of their recent trip "Island Hopping in the Carib-

LOS ANGELES ROCKETRY PANEL HEARS RUSSELL

Howard Eubanks, vice-chairman of the AWS Aircraft & Rocketry Panel, introducing the featured speaker, Byron Russell, at the November 7th meeting

Mr. Russell covered, among other things, a number of automatic welding operations with the inert-gas-shielded tungsten-arc and metal-arc processes

beau" which was thoroughly enjoyed.

Technical speaker was George Spies, of the Air Reduction Co., Union, N. J. His subject was on "Propane and Natural Gas Cutting."

Mr. Spies, in his talk, told the audience the many advantages of using propane and natural gas; these gases are similar in characteristics and can be used in the same equipment as acetylene. They differ, however, in their chemical characteristics as propane is a hydrocarbon, while natural gas is not a specific hydrocarbon as it consists of 80 to 94% methane and 3 to 8% ethane, plus nitrogen and oxygen.

At one time, natural gas varied in mixture by the area from which it was produced but present day practice makes gas uniform in its analysis.

Mr. Spies stated the differences between cutting with propane and natural gas and acetylene, also the four requirements of any cutting operation. In regard to "How Much Oxygen," adjust for best performance—a fuel-rich mixture for quality, slag free cutting of thin plates while oxygen-rich mixture is for fast starts and rip cutting of scaled surfaces. The speaker gave practical tips on how to regulate oxygen in mixtures.

In conclusion, the speaker said excellent results can be obtained from natural and propane gas cutting and that there is a difference from acetylene cutting. To obtain the best results the proper technique must be understood.

A question-and-answer period followed.

HONEYCOMB STRUCTURES DISCUSSED BY LANZARA

The fabrication of minimum-weight structures for elevated temperatures was the subject covered by Albert Lanzara at the Nov. 21, 1957 meeting of the Los Angeles Section

Among the guests attending the meeting were (*left to right*) Hugo Heimke, local ASM program chairman; National President C. P. Sander and National Membership Chairman Charles Smith

Shown (*left to right*) with the guest speaker are J. E. Wilson, chairman of ASM Chapter of Los Angeles; Mr. Heimke; Mr. Lanzara; John Ross, Section vice-chairman; and Dave O'Connor, Section chairman

INERT-GAS WELDING

Huntington Park, Calif.—The November 7th dinner meeting of the *Aircraft and Rocketry Panel* of the *Los Angeles* Section featured a program by Byron Russell [illegible], president and owner of the Airline Welding & Engineering Co. in Hawthorne, Calif.

The meeting was held at the Elks Lodge in Huntington Park with approximately 100 members and guests in attendance.

Byron Russell began his welding career in his home state of Montana in mining camps and on pipe lines. He completed ICS courses in metallurgy and electronics and in 1941 he became a service representative for Linde Air Products in Los Angeles. Mr. Russell resigned from Linde Air Products in 1952 and organized the Airline Welding and Engineering Co. The company began operations as a specialized job shop but soon expanded to include the design and manufacture of automatic welding fixtures which has become an important part of the company's business.

Mr. Russell had the good fortune to be picked by one of the larger TV networks to present his success story called "Men of Achievement," on a coast-to-coast network, a presentation which was very well narrated by Conrad Nagel. Then a picture in color and sound was shown, along with a picture showing the designing and building of welding positioners for current missiles including some developed for the Bomarc missile.

Automatic slides employing inert-gas metal-arc and tungsten-arc welding processes were also shown and discussed along with a display of welded articles ranging from stainless-steel foil of 0.003-in. thickness to vessels welded by mechanized processes.

Upon conclusion of Mr. Russell's part in the program, a short movie in color was shown on furnaced brazing by Western Electric Co.

The entire evening's program proved to be very interesting and was well accepted by everyone present.

HONEYCOMB STRUCTURES

Los Angeles, Calif.—The November 21st meeting of the *Los Angeles* Section featured a well illustrated talk on honeycombed structure used in the fabrication of the Convair's B58 "Hustler."

The subject, "Fabrication of Minimum Weight Structure for Elevated Temperatures," was presented by Albert Lanzara of Convair, Forth Worth, Tex.

Mr. Lanzara, a graduate of the University of Alabama, where he received his Bachelor's degree in the Science of Aeronautical Engineering, has been employed by Convair, Fort Worth Plant of General Dynamics Corp. since 1943. Mr. Lanzara has been associated with the development of silver-brazed and plastic-bonded sandwich sections for

aircraft since the inception of this program at Convair, as design specialist in charge of the metals, materials and processes involved in the development of this highly desirable type of structure necessary for and in the fabrication of the B-58.

Mr. Lanzara's complete knowledge of his subject, well supported with slides, resulted in one of the most interesting programs ever presented on this type of structure.

Upon conclusion of Mr. Lanzara's talk, a color film was shown of the various stages of test runs made by the B-58 prior to being airborne, and then shown in flight.

The meeting was a joint meeting of AWS and ASM members. The AWS Los Angeles Section served as host to the ASM members of the Los Angeles Section with a total attendance of 255 members and guests.

Following dinner and just prior to the introduction of the speaker, a short business session was held at which time Chairman Dave O'Connor of the AWS introduced such special guests as C. P. "Sandy" Sander, AWS National President, C. B. Smith, National Membership Chairman, and John E. Wilson, Chairman, ASM Los Angeles Section, all of whom gave brief talks in line with their official capacities. Mr. O'Connor concluded the evening's events by commending Mr. Hugo Heimke, program chairman for ASM, and John Ross, vice-chairman of the AWS Los Angeles Section, on their coordinated efforts in obtaining a program of such interesting and educational qualities.

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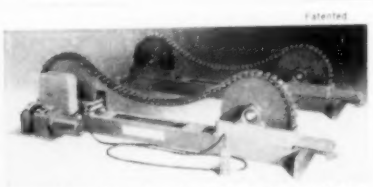

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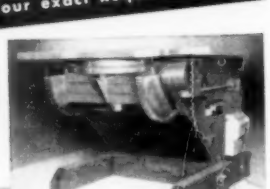

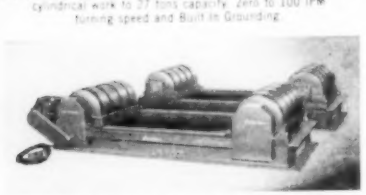

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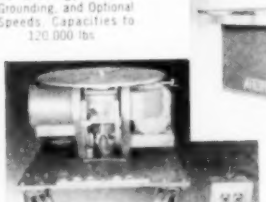

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PLANT TOUR

Elkhart, Ind.—The *Michiana* Section left the welding profession for their October meeting to enjoy a tour through the Robert Gair Division of the Continental Can Co. in Elkhart.

It was surprising to the members to find the Continental Can Co. engaged in making something other than metal containers. At Robert Gair, the product is all paper. It was interesting to find containers for many familiar products.

Perhaps the most fascinating portion of the whole manufacturing process was the making of the "board." Having survived numerous paper drives for various organizations, the members found out what happens to all those old newspapers, magazines etc. which are collected. At the Gair plant, all types of paper are mixed in proper proportion with chemicals to produce a suspension from which new paper is made. The paper making machine is quite interesting, with a slurry entering one end and a continuous sheet of cardboard coming out the other after traversing a veritable maze of rollers that guides the strip for several thousand feet through all operations in the line.

After the cardboard is made, it is printed, cut, folded, glued and otherwise manipulated until it becomes the familiar cartons that we so often bring home. Welding is involved in only the maintenance of the plant. But the problems and processes described by gracious guides made a very enjoyable evening for the AWS.

MAGNETIC-FORCE WELDING

South Bend, Ind.—The November meeting of the *Michiana* Section was held on November 21st at Russ' Restaurant in South Bend. Mr. Myron Zucker of the Myron Zucker Engineering Co., Bloomfield, Mich., gave a very interesting talk on "Magnetic-Force Welding." This is a method of using the welding current to apply forging force to a spot, projection or even flash weld. It is accomplished by placing a single turn coil in series with the welding transformer secondary and the electrodes. The magnetic flux generated in this coil acts on a member attached to the ram in such a manner that additional motion is given to follow up the collapse of projections and to keep adequate force on the weld. A modification of the method uses the magnetic force to cause the upset of

a system that has been flashing from $\frac{1}{4}$ to $\frac{1}{2}$ of a cycle.

These methods of welding are extensively used in the electrical industry to weld contact facings, such as silver to copper, and other combinations not feasible in normal resistance welding procedures.

At this meeting, there was inaugurated the first of a series intended to acquaint members of the section with smaller industries in the area that are involved in welding. A pictorial trip through the Riblet Products Co., narrated by Everette Lyerla (M), showed the operations and equipment of a small shop making a product for other factories. In this case, the product involved was trailer frames. The pictures were taken by Ray Ostrom.

WELDING OF T-1 STEEL

Milwaukee, Wis.—Perry C. Arnold (M), of the Chicago Bridge & Iron Co. was the speaker at the November 15th meeting of the *Milwaukee* Section held at the Ambassador Hotel.

In his talk on "Welding of T-1 Steel," Mr. Arnold pointed out some of the welding problems encountered using T-1 plate. Rebaking electrodes, preheat and cooling rate were given as means of eliminating underbead cracking. His talk was accompanied by slides and a film showing the welding of a 226-ft diam sphere for housing an atomic submarine reactor for the Knolls Atomic Power Laboratory. An interesting discussion period followed his talk.

A film entitled, "Trout-A La-Shoshone" preceded the technical meeting.

ROCKET ENERGY

Manchester, N. H.—The second fall meeting of the *New Hampshire* Section was held at the Queen City Motel on Tuesday evening, October 15th. The meeting was preceded by a social hour and dinner.

At the meeting, the members were privileged to hear Prof. J. A. Browning (M), of the Thayer School of Engineering, Dartmouth College, speak and show by slides "The Industrial Use of Rocket Energy in Flame Cleaning, Flame Hardening and Metallizing." The talk, slides and the manner in which they were presented were received by the members present with the utmost interest.

PIPE WELDING

Newark, N. J.—The *New Jersey* Section met on November 19th at the Essex House Hotel in Newark.

Seventy-eight members and guests listened with interest to the speaker of the evening, R. W. Minga (M), development engineer in the Electric Welding Group specializing in pipe welding applications with the inert-gas process at the Linde Co. Development Laboratory in Newark, N. J.

SPEAKS ON PIPE WELDING

The welding of pipe with the tungsten-arc process was the subject covered by R. W. Minga at the Nov. 19, 1957 meeting of the New Jersey Section

Mr. Minga's subject entitled "Welding Pipe with the Tungsten-Arc Process" was illustrated by slides showing the procedures used. The design of pipe joints, the methods used to control quality, cost comparisons with other methods of welding, were some of the topics treated. In conclusion, Mr. Minga gave a very convincing case in favor of tungsten-arc welding: a lower per joint cost through absence of backing rings, no inter-pass slag removal and a deposition rate of $2\frac{1}{2}$ lb per hr.

There was an interesting question-and-answer period, covering the training of welders, forehand and backhand techniques, the welding of pipe outdoors, pressures used and types of purging gases.

A dinner attended by forty-one members preceded the technical meeting, and the evening's events were concluded by refreshments and the usual get-together.

POWER SOURCES

New York, N. Y.—The Third Fall meeting of the *New York* Section was held on November 12, 1957. A good program had been arranged and the speaker of the evening was Mr. H. J. Bichsel (M), Manager of Arc Welding Department of the Westinghouse Electric Corp., Buffalo, N. Y.

Mr. Bichsel's topic was "Power Sources for Arc Welding," a talk that was received with great interest as it took in not only modern sources but also the history and the very origin of welding.

With the aid of a series of excellent slides, the speaker explained the history and the origin of welding, dating as far back as year 1700, and gave a broad outline of the d-c type of arc welding that was generally used until the beginning of the 1930's when a-c arc welding was introduced, and the type of machinery that was used for this purpose. Mr. Bichsel emphasized the tremendous amount of research work that has been going on in the welding industry, and the power sources that now are more generally used, for example, the se-

PANEL DISCUSSION ON HARD SURFACING

Among those who participated at the Nov. 1, 1957 panel discussion on hard surfacing sponsored by the Philadelphia Section were (*left to right*) J. E. Burke, W. L. Lutes, A. C. Young, C. W. Dunn (moderator) and F. P. Kelly

lenium-type rectifiers which originated in Germany, and from there came to this country. He explained how the selenium stacks made the power sources much more compact and their ability to handle large current capacities.

From the selenium type, the speaker went on to explain the still more compact silicon rectifiers which handle huge currents from relatively small sources. Also, the speaker discussed the heavy welding transformers of from 1500 to 2500-amp capacity at constant potential which are now in general use and which are so constructed for maintenance of a stabilized arc. In addition, the speaker explained some of the latest rectifier-type d-c units now in operation.

An audience of 60 engineers and welders was present. J. J. Mazzafero of the Westinghouse Electric Corp. was the technical chairman for the evening.

The meeting as usual was held at Victor's Restaurant, 1 E. 35 Street, New York City, and an excellent dinner was served prior to the meeting.

STAINLESS-STEEL BRAZING

Knoxville, Tenn.—November technical meeting of the *Northeast Tennessee* Section was a joint dinner meeting with the Oak Ridge Chapter of the American Society for Metals and was held on November 20th.

Fifty-two members and guests, many of whom hold dual membership in the two societies, had the pleasure of being addressed by Mr. Charles E. Rorick of Convair, Fort Worth, Tex., on the subject of "Stainless-Steel Honeycomb Brazing." The talk was prefaced by a brief discussion of the problems encountered in modern high-speed aircraft, such as strength-to-weight ratio, high-temperature strengths, aerodynamic heating and aircraft weight increase and was followed by a slide presentation.

The honeycomb sandwich panel has been the solution to many of the problems encountered. Constructed of silver-brazed 17-7PH stainless steel, a combination of lightness with great strength and heat resistance is achieved.

The descriptive slides showed the history of the developmental stages of fixturing for brazing, atmosphere control and the selection of brazing alloys leading to the present day processing methods.

Special emphasis was placed on in-process quality control necessary for the production of the honeycomb construction, involving core milling, detail part fabrication, assembly of components by resistance tack brazing followed by furnace brazing and heat treatment for mechanical properties.

Airframe construction of the honeycomb type has proved to be a great saving in weight over the conventional spot-welded plate and stringer construction as well as being adaptable to high-temperature service.

GUIDED MISSILES DISCUSSED AT PHILADELPHIA MEETING

Over 150 members and guests attended the November 18th meeting of the Philadelphia Section. Part of the large crowd is shown above

Guest speaker was W. R. Lucas who presented a timely paper on construction problems in the development of guided missiles

Dr. Lucas is shown with Carl Schaub (*left*) and Section Chairman Byron Gates (*right*)

AUTOMATIC WELDING

Lewis Run, Pa.—The *Olean-Bradford* Section met for dinner and meeting on November 19th in the Valley Hunt Club in Lewis Run. J. A. Howery [illegible], assistant manager, Technical Service Dept., National Cylinder Gas Co., Buffalo, N. Y., spoke on "Automatic Welding with CO_2," after which the members adjoined to the welding shop of Tony Pessia in Bradford where a demonstration was held on CO_2 welding using flux-cored wire. An entertaining and instructive meeting was enjoyed by all.

HARD SURFACING

Philadelphia, Pa.—Another fine attendance was registered when 108 came out on a rainy Friday night, November 1st, to take part in a panel discussion on "Hard Surfacing" sponsored by the *Philadelphia* Section. The moderator was C. W. Dunn, Bethlehem Steel Co. Panelists included W. L. Lutes of the McKay Co., E. P. Kelly of Haynes Stellite, and J. E. Burke of the Stoody Co.

GUIDED MISSILES

Philadelphia, Pa.—Dr. W. R. Lucas of Redstone Arsenal, Huntsville, Ala., addressed an enthusiastic audience of over 150 members and guests at the regular November meeting of the *Philadelphia* Section held on November 18th at the Engineers Club.

Dr. Lucas, Chief of the Materials Section of the Army Ballistic Missile Agency, very effectively discussed "Construction Problems in the Development of Guided Missiles." He spoke of the factors that limit missile design such as the lack of suitable materials and the need for adequate processing or manufacturing techniques. His talk dealt with the solutions to some of the problems and

special emphasis was placed on welding techniques and the evaluation of weldments. The program was concluded with the projection of two color films. One of these showed the firings of various Army missiles, while the other demonstrated the Redstone Missile by showing the preparations for firing, controls and the actual firing.

WELDING OF STEEL

Johnstown, Pa.—The special meeting of the *Pittsburgh* Section was held in Johnstown on November 7th at the VFW Post No. 155 for the benefit of the many interested members and guests in that area engaged in industry, using welding to a suitable extent. A splendid dinner was served by the Post to a gathering of 106 members and guests. At the meeting were 114 members and guests, including 25 Pittsburgh Section members.

An excellent presentation on "Welding Procedures for Steel" was given by D. H. Marlin (M), Research Engineer for the Dravo Corp., Pittsburgh.

A sound color film, "Prevention and Control of Distortion in Arc-Welding," was shown through the courtesy of the Lincoln Electric Co., Cleveland, Ohio.

RESISTANCE WELDING

Pittsburgh, Pa.—The regular monthly dinner meeting of the *Pittsburgh* Section was held on November 20th at the Hotel Webster Hall and the auditorium of the Mellon Institute of Industrial Research.

Speaker was F. A. Bodenheim (M), Sales Manager, Welder Division, Federal Machine and Welder Co., Warren, Ohio.

Mr. Bodenheim gave an exceptionally interesting talk on the "Fundamentals of Resistance Welding," following which a 30 minute question-and-answer period brought out many interesting facts. Mr. Bodenheim has a splendid manner of presenting a rather complicated subject and the audience was unanimous in its approval.

"THIS IS CHRISTMAS"

Seattle, Wash.—The *Puget Sound* Section unanimously agreed that the usual Christmas party be cancelled. In its stead, the funds that had been devoted to that purpose are now being used for a scholarship to a deserving student and secondly to the election of retired members of this section to honorary membership therein. Certainly no finer expression of Christmas could exist nor could the Society have a more dignified action directed toward it than the one developed this year by the Puget Sound Section. Truly this concept of duty to the Society and to its personnel and to those who have given so unselfishly of their time, efforts and means over the years is deserving of commendation and recognition as an unselfish deed well done.

Those honored are A. G. Bissell, U. S. Navy, Bureau of Ships, Washington, D. C.; Joseph Holt, Consultant, Seattle, Wash.; Sid Smith, American Bureau of Shipping, Seattle; and J. H. Tadlock, J. E. Haseltine Co., Seattle.

WELDING CLAD STEELS

Rochester, N. Y.—Monday, November 18th, the *Rochester* Section held its monthly dinner meeting at the Liederkranz Club. After an excellent dinner, enjoyed by about 40 members and guests, Mr. Louis K. Keay (M), Technical Service Engineer for the Lukens Steel Co., delivered a talk on welding of clad steels. In the technology of modern pressure vessels involved in nuclear power and corrosive-environment service, the use of clad-steel plates has become an outstanding factor. Mr. Keay covered the methods of fabrication by roll cladding steel with aluminum, copper, stainless steel and other corrosion-resisting alloys. Having given the group an understanding of the fabrication techniques, Mr. Keay then went into extensive detail in describing the welding procedures employed in joining the clad materials. He described the "pit falls" which are present, and described several tests which may be utilized in the evaluation of the cladding-base material bond.

Mr. Keay's talk was thoroughly interesting and the excellent slides showed in detail many of the processes which the speaker described. Before the close of the meeting, the members were reminded to indicate their interest in the educational program to be sponsored by the American Welding Society in the Rochester area.

RESISTANCE WELDING

Saginaw, Mich.—Eighty-one members and guests of the *Saginaw Valley* Section met at the High Life Inn on November 7th to attend a dinner and meeting on resistance welding. The speaker, F. R. Woodward (M), of the Taylor-Winfield Corp., Warren, Ohio, centered his talk around sound color movies on resistance welding. Current designs and applications of electric-welding equipment were discussed and illustrated by exceptional

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Light weight was important in this welded missile component that was required to hold air under 3,000 p.s.i. pressure. After making the root pass weld with the Arcos EB* consumable insert, the weld was completed by submerged arc welding with Arcos CHROMENAR CMV welding quality wire. CHROMENAR CMV was selected because its weld metal could be heat treated to match the base metal with tensile strength in excess of 200,000 p.s.i. and pass x-ray inspection. For help on your welding problems consult ... ARCOS CORPORATION, 1500 S. 50th Street, Philadelphia 43, Pa.

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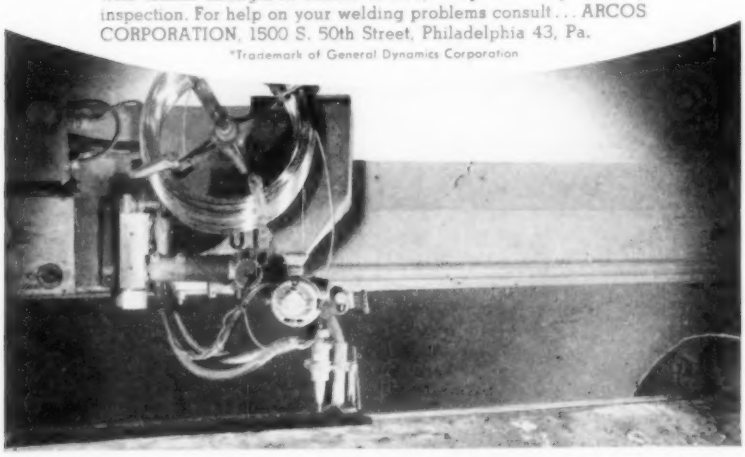

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motion pictures.

The audience showed much interest in the meeting.

In order to further the objectives of the educational values of the SOCIETY, the Saginaw Valley Section, through its Educational Committee, is preparing a lecture series for public attendance.

Current plans call for three lectures as follows:

Wednesday, Feb. 26, 1958—Welding of light metals.

Wednesday, Mar. 5, 1958—Welding of carbon and low-alloy steels.

Wednesday, Mar. 12, 1958—Welding of stainless steels.

All meetings will be held in Saginaw, Mich., which is centrally located in the area covered by the Saginaw Valley Section.

The programs, which will include discussions and illustrations of the topics outlined, will be presented by authorities in their fields, and will be of a semi-technical nature.

The series is directed to give design engineers, operators, instructors, supervisors and technicians a basic understanding of current weld design problems and their solutions, methods and techniques.

Meetings are to be held from 7:30–10:00 P.M. and registration fee will be charged. Those attending all meetings will be presented with a book concerning welding or other appropriate items.

PRODUCTION WELDING

Berkeley, Calif.—Approximately 70 members and guests attended a meeting of the *San Francisco* Section held on November 18th at Spenger's Fish Grotto in Berkeley, to hear a presentation by Byron Russell, President of Airline Welding and Engineering, Hawthorne, on "Production Welding & Welding Fixtures."

Of special interest was a film shown by Mr. Russell in which he was interviewed by film star Conrad Nagel citing Mr. Russell as one of the persons to be honored by the TV program, "Men of Achievement."

The film highlights the rapid growth of special automatic welding fixtures for use on aluminum-titanium and stainless steel as manufactured by the Airline Welding and Engineering Co.

This film has appeared over several west coast TV stations and has been well received.

SELECTING ELECTRODES

San Jose, Calif.—Ninety members and guests attended the dinner and technical meeting of the *Santa Clara Valley* Section held on November 19th

in the Hawaiian Gardens, San Jose, to hear A. M. Croswell [illegible], of the Bechtel Corp., San Francisco, discuss the subject, "Methods of Selecting Electrodes."

Mr. Croswell is senior welding engineer for the Bechtel Corp.'s worldwide operation involving construction of pipe lines, refineries, chemical plants, power plants, nuclear power plants and other industrial developments. He described the methods employed for the selection of welding electrodes for the varied and expansive welding operations performed by his company. It was illustrated how the criteria for selection might be dependent upon the geographic location of the work, the seasons of the year, and of course, whether the work was performed in a shop or in field construction.

Following the very interesting and informative talk, a colored film was shown which illustrated Bechtel's field operations involving welded construction in four different continents and over a dozen countries.

HAZARDS AND PRECAUTIONS

Miami, Fla.—The regular monthly meeting of the *South Florida* Section, held at the M.E.B.A. Hall on November 20th, had an attendance of 65 members and guests.

Jack Meisner, Safety Representative of the Florida Industrial Commission, was the guest speaker. As a safety engineer, he is concerned with the rising costs of compensation, what industry and labor can do about it and what the state is doing.

As to costs, which are composed of direct and indirect items, labor, in general, knows what the direct costs are but has little idea that the indirect costs amount to from four to ten times the direct cost, he pointed out.

The incidence of accidents has been found to be directly proportional to quality of "housekeeping." To his way of thinking, "housekeeping" is the responsibility of both employer and employee.

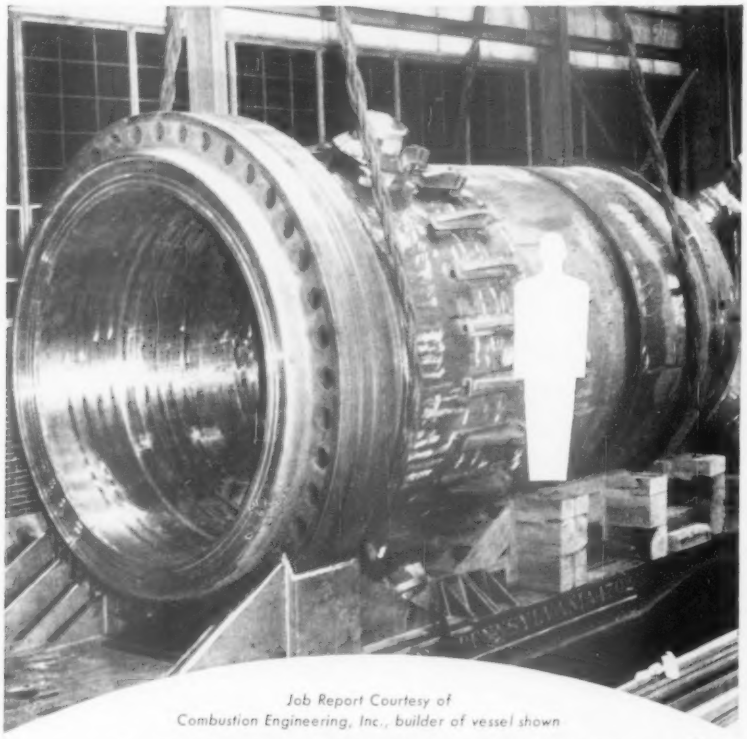
Last, but not least, while the Industrial Commission was primarily set up for the protection of employees, it is now setting up a series of codes on safety which include clothing regulations much to the satisfaction of employers.

PLANT TOUR

Toledo, Ohio—On November 15th, 65 members and guests of the *Toledo* Section toured the new refinery facilities of the Standard Oil Co. (Ohio).

The M. W. Kellogg Co. holds the

This WELDED nuclear pressure vessel holds a practical idea for you



Job Report Courtesy of Combustion Engineering, Inc., builder of vessel shown

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In nuclear installations where radio activity makes weld failure dangerous to personnel and can cause indefinite shutdown, sound corrosion resistant welds are of utmost importance. To inhibit corrosion, portions of the 9 ft. dia. interior of this 33 ft. reactor were overlaid with ¼ in. of 308L weld metal. Submerged arc welding with ARCOSITE S4 flux was used for the job. The girth and longitudinal joints of the low alloy steel plates were also submerged arc welded using ARCOSITE B5 flux. Cost-wise, no other conventional method of cladding was practical. Arcos weld metal quality guarantees corrosion resistance . . . freedom from maintenance. ARCOS CORPORATION, 1500 S. 50th Street Philadelphia 43, Pa.

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prime contract of $34,000,000 on the $40,000,000 project. The new facilities will give the refinery a capacity of 60,000 barrels of crude oil per day after older refinery units are shut down.

Approximately 200 welders are employed on the construction site. Methods of testing pipe and vessel welding were discussed, as were methods of testing welders. It was pointed out to the group that of the 34 large towers and drums, all but eleven will be shop fabricated. The eleven field-fabricated vessels were inspected by the group in their various phases of construction. Five of the eleven field-fabricated vessels were fabricated from material clad with stainless steels.

Even though the huge project was still under construction, the visitors were able to view a model of the new facilities and note the outstanding features of the project. The plant visitation was completed by a fine meal served in the company cafeteria.

RESISTANCE WELDING

Toledo, Ohio—The *Toledo* Section enjoyed a very interesting talk by J. F. Cantalin of the Fisher Body Division of General Motors at the November 19th meeting held at the Maumee River Yacht Club.

Mr. Cantalin's talk covered the use of spot, seam, projection and flash welding as they apply to body assembly work. The speaker also revealed recent improvements which have been developed in body work. These include "portable roller-spot welding" and "mash seam welding." The speaker also cited as an example the evolution of the present seat construction which is now designed to utilize fully resistance welding on a production basis.

TITANIUM

Thompsonville, Conn.—A dinner meeting of the *Western Massachusetts* Section was held on November 12th at the Silhouette Restaurant in Thompsonville, Conn.

Technical speaker was C. E. Hartbower [M], Chief, Metals Fabrication Branch, Watertown Arsenal, who spoke on "The Properties of Titanium and Titanium Arc Welding."

Mr. Hartbower limited his talk to properties of welds and to the problems of welding, especially fusion welding, and supplemented his talk with slides. He explained that while titanium is heavier than aluminum it is lighter than steel and stronger than aluminum. Titanium's resistance to corrosion makes it valuable for aircraft use. The only competitor to titanium at higher temperatures is stainless steel, and the latter weighs considerably more.

The speaker was asked about the use of consumable electrodes in the welding of titanium. He stated that as few passes as possible should be used. Therefore, the border line would be welding $\frac{1}{4}$- or $\frac{1}{2}$-in. plate with tungsten, and thicker plate work should be done with consumable electrodes.

The meeting adjourned at 9:30 P.M.

HEAT TREATMENT

Grand Rapids, Mich.—The regular monthly meeting of the *Western Michigan* Section was held on Monday evening, November 25th at the Varsity Grille in Grand Rapids. There were 34 present for the dinner and they were joined by four more for the "coffee talk" and technical session.

The coffee talk was given by Owen Eister of the C. & O. Railway. Mr. Eister is a member of the Toastmasters Club and gave several humorous poems to the delight of all.

The technical session was covered by Pat Doyen [M], of the Welding Equipment and Supply Co., Detroit. Mr. Doyen spoke on "Heat Treatment-Inert Arc-Metallic Arc Welding of Tool Steels." He also showed some excellent films from the Bethlehem Steel Co. on the making of tool steels. Mr. Doyen pointed out the necessary procedures and kinds of rods to use in welding the tool steels.

SAFETY

Worcester, Mass.—The second meeting of the season of the *Worcester* Section was held at Nick's Grille on November 4th. This being a meeting on safety, there were several members of the local chapter of the Society of Safety Engineers present.

The speaker, Mr. Melvin A. McCully, of John C. Paige & Co., Inc., is a man of national renown in safety engineering. The Paige Co. have clients all over the United States. Their aim is to reduce industrial accidents everywhere, and correspondingly reduce compensation costs and human misery.

Mr. McCully chose as his subject, "Safety Can Be Sold." To sell, we need three items: (1) a product, (2) a salesman and (3) a buyer. Mr. McCully described the functions of all three. He contends that there are four basic methods to be used to sell safety, viz: telling, showing, motivating and doing; and in a factory a supervisor or management have three steps to take: the approach, the demonstration and the close.

In the approach he shows the worker the necessity of eliminating accidents that could cause death and injury. In the demonstration he will discuss figures to prove his point, will analyze local cases as to cause and effect, will point out hazards both physical and human and advance and discuss means of preventing a recurrence of any previous unfortunate happening.

Mr. McCully's definition of an accident is "an unexpected and unplanned happening that may or may not result in death or injury to person or persons or damage to material, machines and equipment."

Mr. McCully believes that to sell safety one must first "communicate," second "motivate." In communication, one must talk in language the receiver will understand, transmit information in small lots, provide opportunity for a feedback. Communication must be on a two-way basis, and all must participate. In motivation, he finds an individual's life is spent in trying to satisfy his various needs. These needs motivate human behavior and in general can be classed as follows: physical needs, social needs and egotistical needs. An appeal along the line of alleviating these three needs will obtain a worker's interest and his cooperation. Explain what there is in it for him.

Mr. McCully's views were very well received. When the question period had been concluded, everyone present had a much better idea of what can be, and is being, done to reduce accidents to a very minimum.

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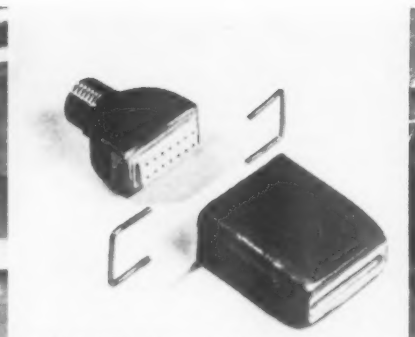
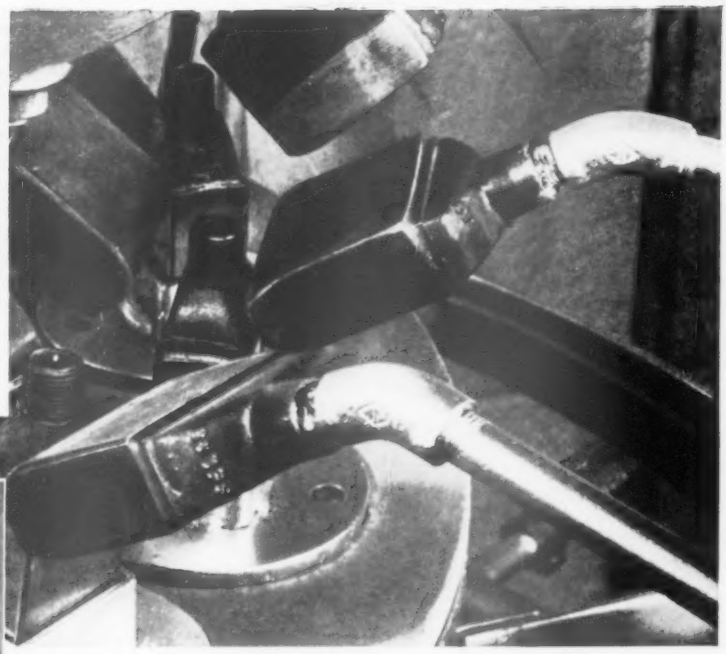
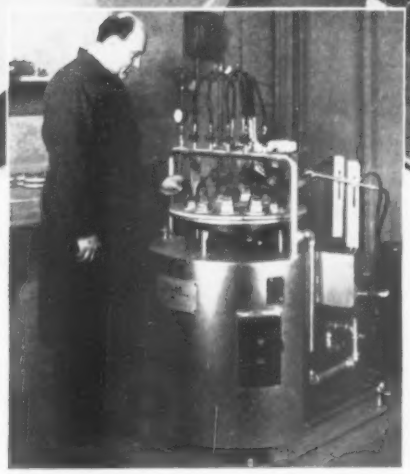


Selas Superheat burner before assembling. Two EASY-FLO 45 preforms of 1 in. by ¾ in. each.





Operator shown placing assembled burners in Selas rotary gas-air equipment to start 75-second brazing cycle. Large illustration shows burners under heat.

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ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,794,110—Method and Means for Removing Metal by Electric Discharges—Charles G. Griffith, San Diego, Calif., assignor to Rohr Aircraft Corp., Chula Vista, Calif., a corporation of California.

This patent relates to apparatus for electrically cutting a narrow deep slot in a workpiece. This patented apparatus comprises a pair of supporting frames, one of which is arranged to support the workpiece, while a thin wire is supported by the other of the frames adjacent the workpiece. Frames are relatively movable to bring the wire to advance within the workpiece area without touching it. Other means supply the wire and workpiece with unidirectional high frequency currents of amplitude sufficient to cause intermittent electrical discharges between the wire and workpiece as the wire is advanced. Another member rapidly vibrates the wire in a direction normal to the plane of the slot being formed in the workpiece as the wire advances.

2,794,111—Actuating Mechanism, Particularly for Strip Welders—Melvin M. Seeloff and Robert Anderson, Warren, Ohio, assignors to The Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

A special fluid actuator, piston and cylinder means are disclosed in this patent for use with flash-butt welding machines. The members are adapted to control a movable platen for carrying out the flashing and upset portions of a welding operation.

2,794,112—Automatic Arc Welder—Edgar W. Crow, Manhattan Beach, Calif., assignor to Northrop Aircraft, Inc., Hawthorne, Calif., a corporation of California.

Crow's patent relates to a specialized type of an automatic welder including an elongated cylindrical workpiece support. Special means are provided for holding the work against a flat surface provided on the workpiece support. Movable welding head means are provided to move along the elongated workpiece support for welding action.

2,794,152—Arc-Machining—Victor E. Matulaitis, Franklin, Mich., assignor to Elox Corporation of Michigan, Clawson, Mich.

This patent relates to apparatus for removing material from a workpiece by electrical discharge. An electrode is provided and means are present to cause an intermittent electrical discharge between the electrode and a workpiece. A power source of relatively high voltage is present, and a second voltage source provides a predetermined lower voltage. Means are actuated by the second voltage source to limit the instantaneous voltage across the gap.

2,794,243—Method of Brazing Corrugated Fins to Flat Tubing—Edmund E. Schweller, Dayton, Ohio, assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

A specialized method for brazing strips of corrugated fins to flat tubing is disclosed in the patent. The patent includes the steps of dipping fins and tubing while pressed together into a hot brazing flux for brazing the opposite peaks of corrugations of the fins to the tubing. Thereafter, the assembly is removed from the hot flux and cooled.

2,794,244—Flash Welding Assembly and Method—Otto E. Uecker, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

This patent relates to a method of making a hollow metal article and includes spacing a pair of hollow members having opposed complementary edge portions in alignment for electrical flash welding action. A thin tubular metal shim is temporarily supported against the inner surface of each member axially outwardly, or spaced from the opposed edge portions thereof. The members are then flash welded together so that the majority of flash metal is extruded within the members at the welded joint and is disposed inwardly of the surface of the shim. Then the flash metal is rough cut to a level substantially flush with the exposed shim surface and thereafter the shims are removed and the remaining flash metal is fine cut to the level of the inner surface of the members.

2,794,409—Edge Bending Mechanism for Spiral Welded Pipe Machine—Jonathan Roy Freeze, Middletown, Ohio, assignor to Armco Steel Corp., Middletown, Ohio, a corporation of Ohio.

A special type of edge bending mechanism of the type indicated is disclosed by this patent.

2,794,755—Flat Powder Stream Forming Process—Fred Moesinger, Jr., Morristown, N. J., assignor to Union Carbide Corp., a corporation of New York.

This patent relates to the art of thermochemically scarfing metal work and a relatively flat stream of commercially pure oxygen is directed against the surface portion of the work at an exit velocity of between 500 and 850 fps. A relatively flat stream of ferrous metal powder is provided and is of relatively round cross section and thereafter the direction of flow of the stream is abruptly changed and confined to a path of increasing width and decreasing thickness. Subsequently, the resulting flat stream is discharged at an exit velocity of between 30 and 350 fps through a relatively wide and thin slot towards the leading edge of the oxygen stream referred to.

2,794,893—Induction Welding—Thomas J. Crawford, Berkley, Mich.

This patent relates to tube welding apparatus wherein a moving metal blank is shaped by progressively bringing the edges thereof together and passing them through an induction heating coil for inducing welding current therein at the point of contact of the edges. A condenser is connected to form a resonant circuit with the coil, and a high frequency electronic oscillator is provided to supply current to the circuit. The oscillator and the circuit are tuned so that the circuit will resonate at a frequency slightly higher than the oscillator operating frequency. Hence, movement of the point of contact with relation to the coil will cause the circuit frequency to vary and produce a change in the current flowing through the coil effective to maintain the induced welding current substantially uniform.

2,794,898—Composite Electrode—Glenn J. Gibson, Berkeley Heights, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

A specialized electrode is disclosed in this patent and it includes a torch having a hollow interior for receiving an elongate electrode. Clamping means are provided in the torch to grip the electrode and reposition it when appreciably reduced in length. The electrode consists of a tungsten rod and a copper tube swedged onto the rod and positioned so that an end of the tungsten rod serves as a terminal for an inert gas-shielded arc.

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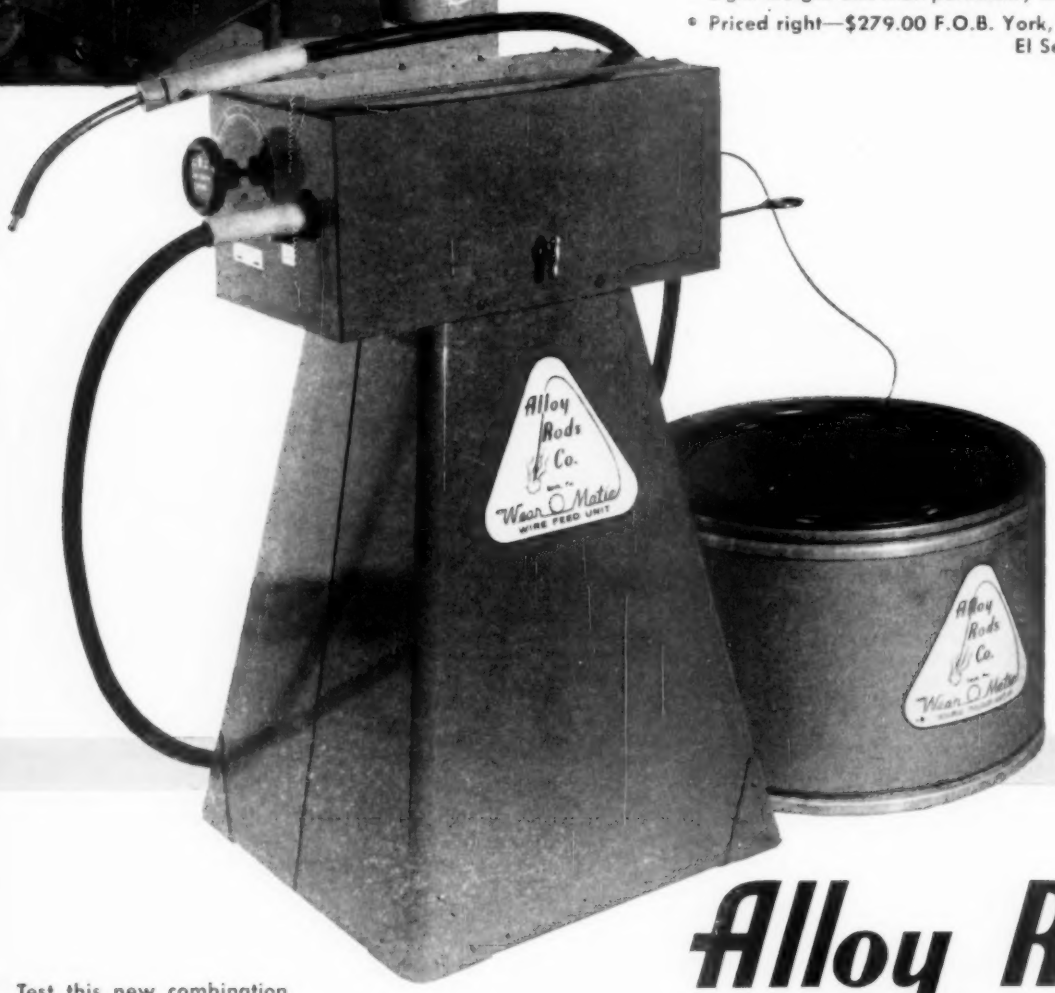

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NEWS of The Industry

Welding Equipment Cooler Introduced by Bernard

A new-type welding-equipment cooler designed primarily to solve the heat-removing problem which, in the past, has tended to restrict the full potentialities obtainable with gas-shielded type arc welding processes, has been introduced by Bernard Welding Equipment Co., Chicago 17, Ill. Applicable to both the

Fig. 1 Complete welding equipment cooler unit

tungsten-arc and the consumable-electrode process, efficient source of coolant for spot welding dies, resistance welding rollers, induction heating coils, automatic welding equipment and copper chill bars.

The manufacturer reports that this cooler provides a reliable and efficient coolant source which is simple in operation, practically fool-proof and exceptionally portable. It eliminates the need for long lengths of hose running

Fig. 2 High degree of portability is demonstrated above

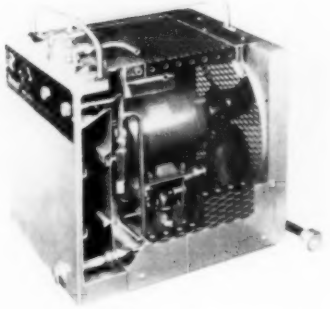

Fig. 3 Cut-away of cooler showing arrangements of parts

from city water mains, or from large storage tanks portable only if mounted on a carriage, eliminating the expense of such plumbing and providing clear works areas.

The operating concept involves the use of a pump which draws a coolant from a small nine-quart reservoir and circulates the coolant through the welding equipment from which it absorbs the excess heat. Upon returning to the cooler, the liquid is passed through a three-stage radiating system. A four-bladed pressure-type fan picks a compression chamber with air from which its only escape is through the radiating units. The unit is no larger than a small travelling bag and weighs only 68 lb. Other than a source of current, the cooler is completely self-contained thus making it equally successful for either shop or field-welding applications.

The pump which circulates the coolant is of a positive displacement planetary gear type. To protect the pump and the welding equipment, a 120-mesh filter is located on the intake side of the pump. The filter is readily removable for inspection and cleaning from the exterior of the cooler. An adjustable by-pass pressure relief valve is provided to maintain constant pre-set coolant pressures, thus protecting the welding equipment. Sealed ball-bearing construction and oversize electrical components, with all operating parts encased in a heavy gage steel cabinet, are used.

A coolant liquid additive prevents corrosion of all parts of the welding equipment through which the liquid circulates and non-evaporating type anti-freeze may be added to prevent equipment freeze-ups when used in the field.

Other details outlined by Bernard Welding Equipment Co. are as follows. Model No. 500 is rated at 500 amp when used to cool any make of gas-shielded tungsten-arc and metal-arc gun or torch, including 15 feet of #8 water-cooled current cable at a 100% duty cycle. With intermittent use, higher amperages can be handled, on the order of 600 and 700 amp depending on the duty cycle, in turn, at lower amperages; at normal duty cycles, the new type cooler is capable of handling two or more welding guns or torches. It has a maximum calorie rating of 250 Btu/min at a room temperature of 75° F. The maximum flow rate of the coolant is 1.9 quarts per min. The pressure of the circulated coolant is adjustable from 0 to 100 lb per sq in.

The cooler provides several safety features for protecting the welding equipment, which makes it impossible for the welding operator to weld without the cooler being in operation. These features include a pilot light indicating when the cooler is operating. As a further safety measure, the coolant flow is always visible to the operator at a visible flow indicator consisting of a transparent dome located on the top of the cooler.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1958 Spring Meeting and Welding Show:
April 14-18, Statler Hotel, St. Louis, Mo.

Midwest Welding Conference
Jan. 29 and 30, 1958, Chicago, Ill. Illinois Tech Chemistry Bldg., 3255 S. Dearborn St.

IAA

March 19-21. Fifty-eighth Annual Convention, Bellevue Stratford Hotel, Philadelphia, Pa.

14th Annual Convention, Americana, Miami Beach, Fla.

Handy & Harman to Open New Plant

Handy & Harman is building a new and larger plant at 33 North Gibson Road, El Monte, Calif.

The new plant, complete with offices, laboratory, refinery, operating area

and warehouse, will cover more than 23,000 sq ft. It will have twice the capacity of the plant which the company opened in April 1947 at 3625 Medford St., Los Angeles. As the company's fifth plant, it is scheduled to begin operating in February 1958. The Los Angeles plant then will close.

Upon completion of construction by the Austin Co., of Los Angeles, which also designed the structure, the new plant will operate under the supervision of H. A. Folgner as manager. Mr. Folgner currently is manager of the Los Angeles plant.

Airco Acquires Distributors

The businesses of Arcway Equipment Co. of Philadelphia, Baltimore and Pittsburgh, and Welding Sales & Engineering Co. of Detroit, both distributors of arc-welding machines, electrodes and accessories, have been acquired by Air Reduction. Airco also acquired the G. E. Welding Department's direct sales outlet at Tulsa, Oklahoma, following General Electric's recent discontinuance of their welding line.

Open House at Pacific Metals

Pacific Metals Co. held an open house and welding clinic Oct. 15-17, 1957 at their new plant located at 1900 Third St., San Francisco, Calif.

The Westinghouse line of welding machines and electrodes was displayed and demonstrated. This included manual, semiautomatic and automatic operations.

PLAN NOW
TO ATTEND
1958 SPRING MEETING

MEXICAN AFFILIATE ESTABLISHED BY EUTECTIC

First sales meeting of Eutectic Welding Alloys Corp.'s affiliate in Mexico City, Compania Mexicana De Soldaduras Eutectic A Baja Temperatura S.A. Mrs. Roma Garzione Rao, vice-president of Pan American Eutectic Welding Alloys Co., Inc., supervised the setting up of the new branch and was assisted in the developing of the sales force shown standing, by Mr. John B. Knight, Jr., (seated right) special representative for Latin America. Mr. Marco F. Ayora, (seated left) regional technical representative, trained the staff on Eutectic's "Low Temperature Welding" procedures and materials. The Mexico City plant is located at Maestro Antonio Caso No. 89, Mexico 4 D.F.

Arcair Removes Hard-Surfacing on World's Biggest Shovel

Arcair torches and Copperclad electrodes have cut maintenance costs substantially on The Mountaineer. Speeding hard surface removal on manganese and high-carbon pads, chains, bucket lips, teeth and sprockets, Arcair does the job 10 times faster than former grinding or chiseling methods.

With surfaces Arcair-clean and Arcair-smooth, welders find re-surfacing or other maintenance welding on The Mountaineer an easier, faster job with better fusion to the parent metal.

Torch technique takes only 15 minutes to learn. Basic simplicity—electric arc plus ordinary compressed air—makes the patented Arcair torch, with Arcair Copperclad electrodes, the new, efficient, money-saving answer to most metal removing problems.

See proof of performance from many industries! WRITE TODAY for FREE BROCHURE.

Arcair COMPANY
431 S. Mt. Pleasant St. Lancaster, Ohio

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CUT WELDING COSTS WITH

Up-to-the-minute designs

G-E Convertible Ignitron has built-in thermal-contact bracket (circle) that will carry a thermostat for over-temperature protection, or for water regulation. Thermostat which is shown here is equipped with flying leads.

Convertible Ignitron above has a terminal-block thermostat. Bracket mounting of thermostat permits the same ignitron to be used in standard or temperature - controlled applications. You save stocking two tubes.

More hours of dependable service per dollar!

Here's why!

STABILIZED STAINLESS-STEEL JACKETS

General Electric uses *stabilized* steel for both inner and outer ignitron water-jackets. Characteristics of this material—its expansion and contraction, strength, chemical content—do not change with time or use. G-E ignitrons retain their full structural strength for life, adding to dependability and cutting tube replacements.

HIGHEST-QUALITY IGNITORS

General Electric ignitors—specially made and tested—will outlast others by as high as 2 to 1. Examples of 4-years-and-over G-E ignitor life are common; also cases in which G-E ignitors have outlived the tube. Carefully controlled materials; holding the ignitor resistance to close limits; precision grinding—these are reasons-why.

CONTROLLED-GRAPHITE ANODES

By using a specially-developed electronic grade of graphite, with both density and size of particles controlled to tight limits, General Electric is able to build ignitron anodes that stand up under extremely long and hard usage. The anode graphite is further treated at the General Electric factory for maximum life in heavy-duty service and under high-temperature conditions.

TRIPLE-DISTILLED-MERCURY POOLS

Mercury in G-E ignitron cathode pools is distilled to a point where impurity content is only 1 in 100,000 or less. Organic impurities, which can bring about gas formation, and inorganic materials, which can cause the ignitor to plate over, both are held to a virtually irreducible minimum. Increases tube dependability.

FACTORY-TESTED AT FULL RATINGS

Exclusive with General Electric is the special factory test equipment that operates G-E ignitrons at full ratings under actual welding conditions. You buy tubes proved-in-advance for service in your plant. Every General Electric ignitron, moreover, is checked at the factory for the possibility of vacuum or water-jacket leakage.

CONVENIENT SLIP-ON TERMINALS

No more need to remove the terminal bolts completely when installing or replacing General Electric welding ignitrons! Merely loosen the nut and slip off one terminal with its slotted design, slip on the new terminal—then re-tighten. It's as easy and fast as that, and you run no risk of misplacing the nut-and-bolt assembly. This up-to-date feature saves you time and trouble.

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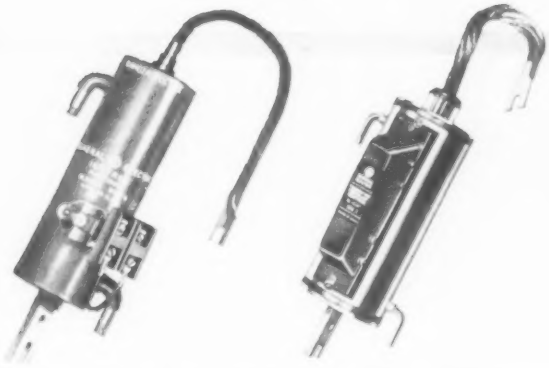
G-E LONG-LIFE IGNITRONS!

meet every replacement need.



General Electric Plastic-coated Convertible Ignitron has a plastic covering to shield workers from hazardous voltages. Plastic is red for warning. "Danger . . . voltage" is stamped on outside of each tube conspicuously.

G-E Temperature-controlled Ignitron is the finest tube of its kind. Over-temperature control . . . water regulation . . . both are built in. The tube is pre-adjusted at the factory for lifelong efficiency of operation when installed.

Shows you how to squeeze maximum value out of every ignitron dollar! This complete guide to ignitron care and maintenance is a "must" for your shop files. Solves dozens of ignitron operating problems; answers scores of questions. Get your *free* copy from your local G-E tube distributor!

You cut welding costs with G-E ignitrons because (1) their life-span is greater, giving you more service hours per dollar, and (2) G-E ignitrons are more dependable, requiring minimum tube replacement. Welder downtime is reduced.

Quality of General Electric ignitrons sets the pace for the industry. Study the advantages of these tubes at left. Every design plus can be entered on the credit side of your plant ledger—means a saving in upkeep, in inventory of replacement tubes to be carried on hand, in non-productive welding time.

Check, too, the wide range of G-E ignitrons manufactured and available to you! Convertible types . . . . . G-E temperature-controlled ignitrons . . . . . plastic-coated tubes for extra safety. All can be obtained in 40-, 140-, and 355-amp capacities. Every welder need is met. You can have G-E top ignitron quality right through your plant, with the greater economy—immediate and long-term—this brings.

And your tube source is conveniently close at hand. Your General Electric tube distributor—right in your area—stocks G-E ignitrons, knows ignitrons, knows your plant requirements, makes fast deliveries to your door. Phone him today! *Distributor Sales, Electronic Components Division, General Electric Company, Owensboro, Ky.*

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INTERNATIONAL WELDING NEWS

Welding Conference in Czechoslovakia

by Dr. J. Krotkovsky

The Welding Research Institute in Bratislava, Czechoslovakia, a member of the International Institute of Welding, together with the Slovak Academy of Sciences and the Welding Section of the Czechoslovak Scientific-Technical Society held their Eighth Welding Congress on the 17th and 18th of September at the academy headquarters in the castle of Smolenice, near Bratislava. One hundred and fifty welding specialists, including the foreign delegations from the USSR, Germany, Poland, Bulgaria and France, were present. The leading topic of the Congress was: "Welding of Heat-Resisting Materials."

Professor Jozef Cabelka, director of the Welding Research Institute in Bratislava and vice-president of the Slovak Academy of Sciences, opened the Congress.

The leading report was the paper of Professor Ing. Dr. Jozef Cabelka entitled, "Problems of Welded Structures of High Heat-Resisting Materials."

In this communication the actual problems of materials for power-equipment structures of high parameters were analyzed in respect to welding. The author criticized the steels currently furnished for these purposes and pointed out how metallurgy influences the properties of the steels produced. He particularly mentioned the influence of gases, namely that of oxygen on the intercrystalline cohesion and the formation of the Sigma phase in heat-resisting austenitic steels. He indicated the favorable properties of the austenitic chrome-nickel steel 16.13. Further he mentioned the respective welding methods of these steels and demonstrated typical joints and welded structures of heat-resisting materials. Professor Cabelka also described the development of a test-boiler unit for high parameters being solved in the Welding Research Institute in Bratislava, for testing purposes.

Of the foreign lecturers the paper of Ing. Zaletajevova of Cnitmas, Moscow, was very informative. She described the proceedings of a complex method of developing heat-resisting steels. The lecturer indicated the indispensability of developing steels of high parameters where a higher resistance is obtained by application of chrome, tungsten, nickel and titanium. The Soviet expert enumerated quite a range of steels developed in their institute and applied in industry as pearlite and austenite steels, 15 Cr 15 Ni 3 Co, on a nicked basis for higher temperatures than 700° C, steel of 12% Cr, 1% Mo and 2 to 4% W for forged rotors, steel 18 8 with 3% Nb for super-heater pipes for temperatures of 500-700° C. The research in steels for temperatures over 700° C is not yet terminated.

Professor Ing. Dr. F. Erdmann-Jesnitzer of the Mining Academy in Freiberg, in Eastern-Germany, dealt in his communication with the physical determination of welding defects caused in non-alloyed carbon steels by hydrogen. He analyzed the behavior of soluble hydrogen in steels as well as the findings of systematical testing carried out in Freiberg. The theory resulting from these tests in Freiberg enables the metallurgist to explain root-cracking, formation of "fish-eyes" as well as brittleness as a consequence of pickling. This theory shows at the same time the delusiveness of measuring the hydrogen contents in metals. Consequently a new measuring method has to be introduced.

Another German delegate Ing. K. Mrosko of the Central Welding Institute in Halle spoke about "The Research of Precheating in Welding Heat-Resisting Steels." The lecturer stated that the influence of carbon is more important for the resistance of steels than that of other elements, but pointed out that the contents of carbon often cause the formation of martensite, which danger can be eliminated by preheating.

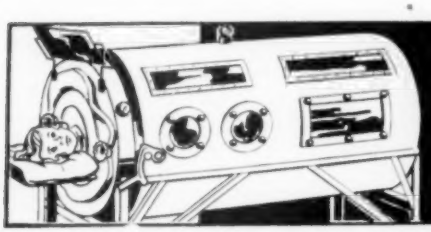
The French delegate, Professor Ing. F. H. Gerbeaux of the Paris Institute de Soudure, reported about the welding of heat-resisting steels, which he divides into carbon and low alloyed steels, ferritic and austenitic stainless steels and high-alloyed heat-resisting steels. The lecture gave a detailed interpretation of the results and the experiences of the French welding engineers in the welding of these and of high alloyed steels. In the course of the following discussion he confirmed that this way — followed also by our research — is the right one, as to the technology of high-alloyed steels of difficult weldability.

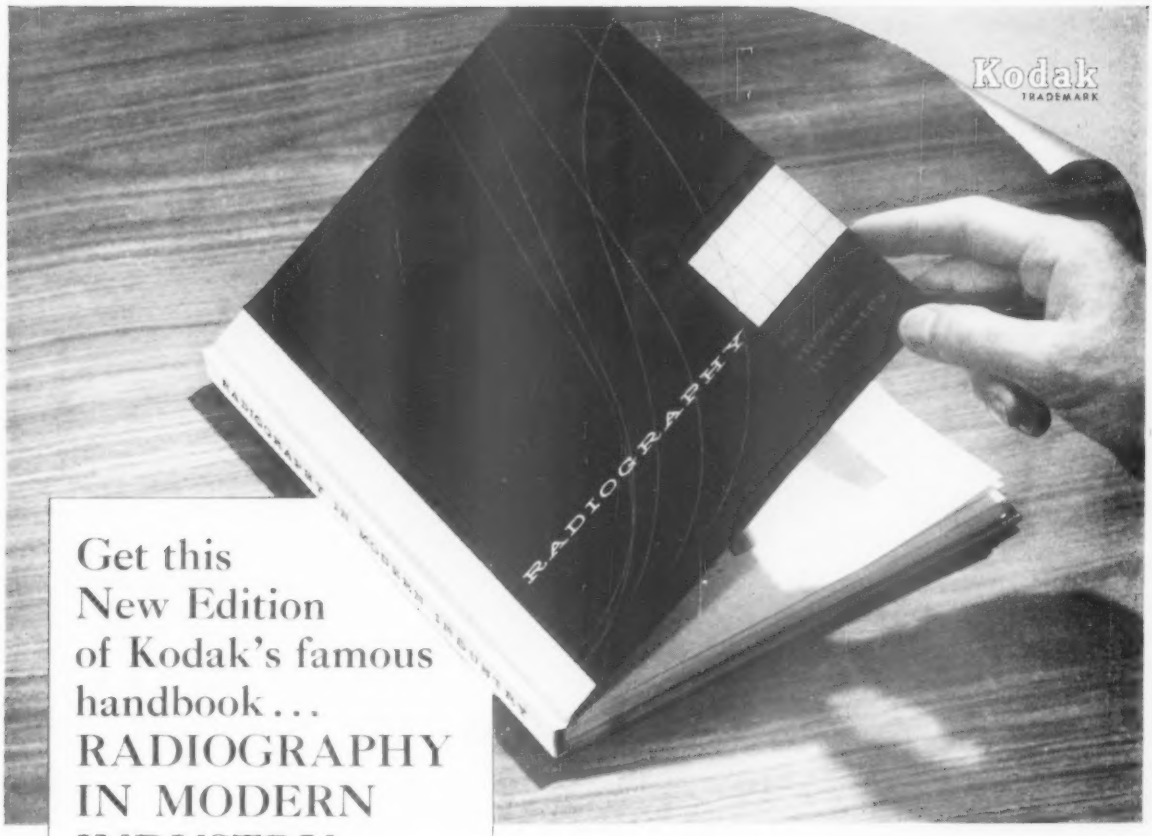
The Czechoslovak specialists dealt in their reports and communications with the problems about solving the structures of high-capacity turbines and the equipment of power stations. The representative from the Institute of Material and Technological Research in Prague, Dr. J. Koritta, spoke on the subject, "Hardfacing Alloys on Heat-Resisting Material and its Thermal Treatment."

Further lectures were held on these important topics: "Economic Heat-Resisting Steels Mn-Cr 17 7, and their Chemical, Physical and Mechanical Properties"; "Heat-Resisting Steels for Constructing Steam-Turbines"; and "The Latest Czechoslovak Types of Ferritic-Pearlitic Steels for the Power Industry."

This significant International Congress was concluded by a speech of Professor Cabelka ending thus: "To become the vanguard of welding, our chief task must be: to develop the material for the power equipments suitable for high operating parameters, further suitable weld material, to develop the correct technology of steel structures and introduce an economic technology of welding production."

Dr. Krotkovsky is a member of the Welding Research Institute, Bratislava, Czechoslovakia.





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Victor Appoints Deveau

Victor Equipment Co. announces the appointment of Richard J. Deveau, Woodbridge, N. J., as a direct factory representative for the East Coast. After high school and since 1951 he worked

Richard J. Deveau

for Linde Co. Starting there in the plant department on assembly line, then to inspector on all types of torches and regulators, Mr. Deveau became an apparatus technician in sales and service department.

His duties entailed servicing all types of welding and cutting apparatus, working with direct customers and in assisting salesmen in their apparatus problems.

Taylor-Winfield Enlarges Production

The Taylor-Winfield Corp., Warren, Ohio, has purchased the exclusive lines of metal-forming and work-handling machinery formerly built by the Struthers-Wells Corp., Titusville, Pa.

This acquisition permits Taylor-Winfield to design and build coordinated production lines to process coil or strip through to the finish welded product. The Warren firm will also manufacture individual metal-forming machines and will provide repair, redesign and replacement service for metal-forming and work-handling equipment previously manufactured by Struthers-Wells.

T. S. Long, Taylor-Winfield vice-president and general manager, described the acquisition as a move to improve service to sheet metal fabricators.

Mr. Long added that many users of resistance welders require metal-forming and work-handling equipment installed on welders. He said Taylor-Winfield will now be able to match this associated equipment more closely than was previously possible.

Filmstrips

The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio, has released three new filmstrips entitled: "Welding Cast Iron With the Arc Welder"; "Hard-Surfacing Farm Equipment with the Arc Welder"; and "Heating, Brazing, Soldering and Cutting with the Arc Welder." These filmstrips were prepared by the Foundation and the Vocational Agriculture Service of the University of Illinois.

Designed to aid high school shop instructors teaching arc welding, these three filmstrips complete a series of six. As indicated by the titles, the first and second strips explain and illustrate some of the advanced techniques of welding which are most useful on the farm. The third strip reportedly shows how the farm welder may be used for non-welding purposes to make the machine a versatile metal-working outfit for the farm shop.

The strips are silent, 35-mm film containing approximately 40 to 45 frames and may be purchased in single frame size for $1.00 each in the USA (postage prepaid) or $1.50 each elsewhere. The entire set of six filmstrips may be purchased for $5.00, postage prepaid, $5.50 outside the USA.

Rego Names Twigg

The Rego Division of the Bastian-Blessing Co. recently announced the promotion of John A. Twigg to the position of assistant sales manager of the High Pressure Gas Equipment Division. Mr. Twigg will assist Sales Manager J. K. Calhoun with the sale of gas welding and cutting equipment, gas plant equipment, cylinder valves, manifolds, oxygen therapy equipment and custom made equipment.

Mr. Twigg has been associated with

John A. Twigg

the Bastian-Blessing Co. for three years. During this time he has worked exclusively in the sale of products for the high pressure gas industry.

Delta Welder Elects Kendall

The election of John B. Kendall as vice-president of Delta Welder Corp., Detroit, Mich., has been announced by Harry E. Day, president.

Mr. Kendall was formerly in charge of

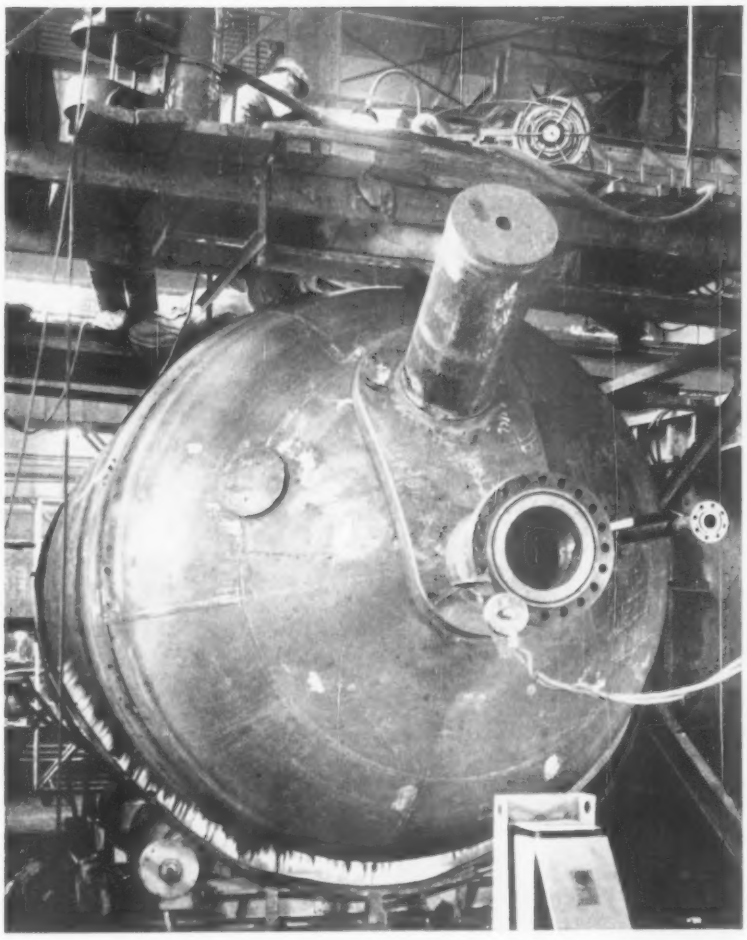
John B. Kendall

the Ford Motor Co. Chicago Stamping Plant, previous to which he managed the Ford Stamping Plant at Buffalo, N. Y.

Other Delta executives are W. H. Hutchins, treasurer, R. J. Clifton, sales manager, and J. R. Carswell, chief engineer.

WELDED EQUATOR RING

The equator ring of a 190-ft diam Hortonsphere—to serve as housing for an atomic reactor—has been completed at the Dresden Nuclear Power Station near Chicago. A 100-ton derrick, with a 170-ft mast and a 135-ft boom, is mounted on a 210-ft tower to lift steel sections into place for welding. The giant Hortonsphere is being fabricated and erected by Chicago Bridge & Iron Co.



When fabrication codes demand 100% X-ray inspection...

SPECIFY *Drawalloy* CORPORATION

Stainless Steel Welding Wire

In hundreds of applications, *Drawalloy* wire has been put to the test . . . X-ray, dye check, pressure and service and with the same consistent result—OK as welded. That's why Frank Iapalucci, Manager of Welding Engineering for Baldwin Lima Hamilton, Eddystone, Penna., selected *Drawalloy* chrome-moly wire for the automatic welds on this reactor. The vessel is constructed of A 301-54T Grade B firebox quality steel ranging in thickness from 5-1/16" to 2-5/8". *Drawalloy* 1-1/4 Cr, 1/2 Mo wire was used for all submerged arc joints.

When inspection by X-ray is required, don't gamble . . . rewelding is expensive . . . specify Drawalloy "quality controlled" wire. *Drawalloy* stainless steel welding wire is produced to strictly controlled specifications to provide the right chemistry, finish and temper for smooth operation in your equipment and to provide X-ray quality welds.

Why not discuss your stainless welding wire needs with your *Drawalloy* Distributor or Representative . . . a man ready to help you. Bulletin 355-DC provides complete information on every grade of *Drawalloy* wire. Write to: Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Pennsylvania.

DRAWALLOY
CORPORATION
YORK, PENNSYLVANIA

THE WIRE MILL FOR THE WELDING INDUSTRY — STAINLESS STEEL · HARD SURFACING · TOOL STEEL

For more details, circle No. 21 on Reader Information Card

P&H Appoints Delta Oxygen

W. R. Stephens, sales manager for the Welding Division of Harnischfeger Corp., Milwaukee, Wis., announced the appointment of Delta Oxygen Co., Inc., Memphis, Tenn., as distributor for the complete line of P&H welding equipment throughout the state of Arkansas and the trading areas of Memphis, Tennessee, Paducah, Kentucky and Greenwood and Greenville, Mississippi.

Delta Oxygen, one of the South's largest welding suppliers, has four branch offices and twenty-five dealers in its territory and furnishes route service with a fleet of over thirty trucks. In addition, a full time service and repair department is maintained to care for customer problems and service.

Design Competition

The James F. Lincoln Arc Welding Foundation's annual mechanical and structural design competition offers 46 cash awards to undergraduates. Top award is $1250. Awards are made in two separate competitions, one for mechanical designs and one for structural designs. Open to undergraduates only, the competition offers awards for the best designs of a machine, machine part, structure or structural component which makes a significant use of welding. Designs made as a part of regular school work may be used. Entries may be submitted after graduation or the close of school term. Rules are available from the James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio.

Victor Story to Appear on TV

The story of L. W. Stettner and Victor Equipment Co. of San Francisco will be seen on "Career," a television program dramatizing the achievements of men and industry on a nationwide release over the next few months.

Mr. Stettner actively continues today a career which started back in the pioneering days of the welding industry. His contributions to the industry were recognized by the International Acetylene Association in presenting him the 1956 James Turner Morehead Medal. Mr. Stettner is a member of the American Welding Society.

A 30-minute color and sound film, "Decades of Quality and Service—the Victor Equipment Company Story," depicting the growth of the company from a small welding shop to its present widespread manufacturing and distributing activities, is now being made available for showing to dealers, friends and customers of the company.

Progressive Welder Elects Heiden and Rose

The board of directors of Progressive Welder Sales Co., 915 Oakland Ave., Pontiac, Mich., announces the election of Ray W. Heiden as president and general manager of all the company's plants and operations. This appointment will fill the vacancy in that office since the death of Fred H. Johnson, former president and the company's founder.

President Heiden immediately announced the appointment of Harry S. Rose as vice-president, national sales manager and member of the board of directors of the company. Mr. Rose is a member of the American Welding Society.

AISC Elects Officers

N. P. Hayes, president of Carolina Steel and Iron Co., Greensboro, N. C., was re-elected president of the American Institute of Steel Construction at its 35th annual convention held October 7–10 in Coronado, Calif.

The other officers, who also were re-elected, are: first vice-president, H. Buckley Dietrich; second vice-president, James M. Straub; secretary, M. Harvey Smedley, New York City; and, treasurer, Erwin P. Stupp.

Norris-Thermador Warehouses in Texas

According to a recent announcement from Norris-Thermador Corp., 5215 S. Boyle Ave., Los Angeles 58, Calif., the warehousing of acetylene cylinders is now being maintained at their plant on 5100 New McGregor Highway, Waco, Tex. Carbon-dioxide cylinders will also be stocked at the same location.

Claude Michael Opens Branch

Claude Michael Agency, soldering material specialists, whose head office is in Glendale, Calif., opened a branch office at 499 Hamilton St., Palo Alto, September 16th to serve Northern California. E. T. James has been appointed sales representative in charge of the new office. Mr. James has had considerable experience in the electronic field where soldering application and hermetic sealing were involved. He will concentrate on servicing the Bay area, San Jose and Sacramento.

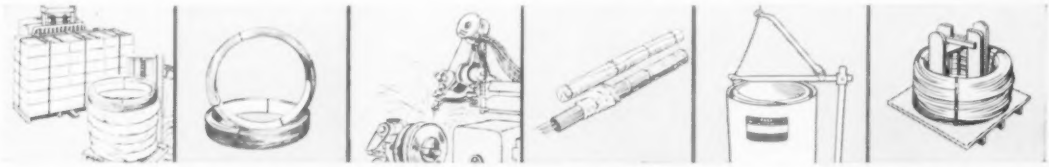
Claude Michael Agency carries a full line of solder, fluxes, fusible alloys, silver brazing alloys, soldering equipment, wire strippers, hand tools and spray paints.

WEAR PROBLEM...
INSIDE OR OUTSIDE.
ONE SOLUTION!
ALL-STATE
NO. 13 NICKEL SILVER BUILDUP ROD
ALLOYS
All-State
FLUXES
for welding • brazing • soldering • tinning • cutting
Users Report on Cams: "Using your No. 13 rod to build up such surfaces, we have had 3 to 5 times the cam life."
Users Report on Wrist Pin Holes in 500-lb. Pistons: "No. 13 enabled successful repair where 200 degrees more heat would have spoiled everything. There was no warpage."
For Instruction Book on 62 alloys and fluxes write All-State Welding Alloys Co., Inc. White Plains, N. Y.
ALL-STATE ALLOYS AND FLUXES
REQUEST COMPLETE LIST OF THESE PRODUCTS FOR PROBLEM SOLUTIONS
For more details, circle No. 22 on Reader Information Card

PAGE Welding Wire

The RIGHT Packaging for the RIGHT Wire

• When you choose PAGE Welding Wire, you are assured of getting the exact wire for your application—and receiving it packaged to provide maximum protection and convenience. PAGE has developed a packaging program to cover practically every requirement in the broad fields of automatic, semi-automatic and manual welding. Coils, reels, bundles, cartons, Leverpaks, Payoffpaks, Payoffpallets... PAGE has them all! Look to PAGE for the *right* packaging of the *right* wire.



Wrapped Coils—Coils in Cartons | Welding Wire in Coils | Handy Reels | Gas Rod Packing | Payoffpaks and Leverpaks | Payoffpallets

This Chart Shows How PAGE Offers The Exact Packaging You Want

PACKAGING ↓ / PAGE WIRE for →	Gas-shielded consumable electrodes: Automatic Welding	Gas-shielded consumable electrodes: Semi-Automatic Welding	Filler wire for automatic or manual Inert Gas Welding	Submerged Arc Welding	Straight and cut lengths Bare wire: Manual Electric Welding	Straight and cut lengths Bare wire: Oxy-acetylene Welding
25-lb. or 60-lb. coils wrapped in waterproof paper, steel-strapped, single or palletized.	✓	✓	✓	✓		
25-lb. or 60-lb. coils in individual cartons, single or palletized.	✓	✓	✓	✓		
120 or 180 lb. (22"/24" I.D.) coils, paper-and-burlap wrapped, or in cartons, palletized.	✓			✓		
Special coil sizes (on application).	✓	✓	✓	✓		
25-lb. reels (spools) in carton to fit all standard machines; single or palletized.	✓	✓	✓	✓		
Leverpaks, 15" dia., 25-lb. coils (12" I.D.x2½" wide); Leverpaks, 17" dia. 50/60-lb. coils (12" I.D.x4" wide).	✓	✓	✓	✓		
Payoffpaks: 20" dia. size holds up to 500 lbs.; 23" dia. size holds up to 700 lbs.	✓	✓		✓		
Payoffpallets, holding 900-1200 lbs. of wire (3/16" to 3/8" sizes, incl.) coiled around pedestal on a wooden pallet.				✓		
Paper-and-burlap wrapped bundles, containing 50 lbs. of rods in 36" lengths.			✓			✓
Fibreboard cartons, containing 10 lbs. of rods in 36" lengths; single or boxed. 50# and over.			✓			✓
Burlap-wrapped 50-lb. bundles of bare wire electrodes in 14" and 18" lengths.			✓		✓	

33 DIFFERENT ANALYSES

PAGE covers the field of applications with *33 different analyses:* heavy automatic submerged arc..light manual submerged..inert gas manual...automatic, tungsten or metal arc, and oxy-acetylene gas welding.

Look to PAGE for your needs for automatic welding wire, gas welding rods, bare electrodes or metal spray wire.

PROMPT DELIVERY FROM LOCAL STOCKS

PAGE welding wire and rods are available from your nearby PAGE Distributor or PAGE warehouse stocks (*see list at right*).

Send for These...

- **Folder DH-402A** PAGE Submerged Arc and Inert Gas Welding Wire
- **Booklet DH-1277** PAGE Gas Welding Rods
- **Welding Rod Comparison Chart**

Page Steel and Wire Division
AMERICAN CHAIN & CABLE

ACCO

Monessen, Pa.*, Atlanta, Chicago*, Denver*, Detroit, Houston* Los Angeles*, New York, Philadelphia*, Portland, Ore. San Francisco*, Bridgeport, Conn.

*Indicates PAGE warehouse stocks

ACCO for Better Values

For more details, circle No. 23 on Reader Information Card

PERSONNEL

Koepenick New President of Electronic Welding

Fredrick R. Koepenick, former plant supervisor of Sciaky Brothers' Western Research Division, was elected president of Electronic Welding, Burbank, Calif., at a recent meeting of the corporation's board of directors. Mr. Koepenick,

Ray Koepenick

an active member of the Los Angeles Section of the AMERICAN WELDING SOCIETY, was also employed as a resistance welding engineer with Boeing Airplane Co. in Seattle. At Electronic Welding he will be in charge of all company activities centering around prime and subcontracts for military and commercial component fabrication involving resistance and or fusion welding.

Cossaboom Appointed by Westinghouse

F. J. Purdy, marketing manager for Westinghouse Electric Corp.'s welding department, has announced the appointment of Gordon E. Cossaboom as coordinator of product service. In his new post Mr. Cossaboom will be responsible for customer service in negotiations involving such matters as warranties, renewal parts and accessory items.

Before this appointment Mr. Cossaboom was a member of General Electric's welding department, first as a product design engineer and later as a product planning specialist. Mr. Cossaboom is an engineering graduate from Northeastern University and holds a master's degree in welding engineering from Ohio State University.

He is a member of the AMERICAN WELDING SOCIETY.

Wells Joins M&T

Metal & Thermit Corp., 100 Park Ave., New York 17, N. Y., announces that Burton A. Wells has joined its welding sales organization and will serve Murex users in the Dallas, Texas area.

Mr. Wells has represented the General Electric Co. for the past seven years in the welding field.

He is a member of the AMERICAN WELDING SOCIETY.

Learmont Awarded Lincoln Prize

Tom Learmont, engineer in charge, quarry and mining excavators, for Bucyrus-Erie Co., South Milwaukee, Wis., has received the $5000 First Award from the James F. Lincoln Arc Welding Foundation, Cleveland, in a national competition sponsored by the Foundation for the design of machines improved through the use of arc welding.

The winning design was for the welded steel base of Bucyrus-Erie's

Tom Learmont

Model 1650-B, the "River Queen," a special long-range stripping shovel equipped with a 55-cu yd dipper. The machine, introduced to the industry in May, is now stripping overburden at an open-pit coal mine in western Kentucky.

Mr. Learmont was the principal designer of the huge, 2400-ton power shovel, one of the largest mobile land machines ever built in the United States. It is taller than a 13-story building, heavier than a Navy destroyer, and is able to take more than 80 tons of rock and earth overburden in a single bite. Welding saved 22% in weight, 15% on material costs with a net manufacturing savings of 24%.

Mr. Learmont is a member of the AMERICAN WELDING SOCIETY.

Champion Named to New Post

The Champion Rivet Co., E. 108th & Harvard Ave., Cleveland, Ohio, announces the promotion of David J. Champion to General Sales Manager. Mr. Champion has held the position of sales manager for the last two years and prior to that time, headed up the reorganization of Champion's Mexican subsidiary, Champion de Mexico located in Mexico City.

The Champion Rivet Company also announces the addition of Joseph DeSanto, Robert Casiek and Dick Capuano to its Chicago sales force.

The Messrs. Champion, DeSanto and Casiek are members of the AMERICAN WELDING SOCIETY.

Trecot Appointed by Eutectic

Appointment of Frank P. Trecot as a district engineer for Eutectic Welding Alloys Corp., Flushing 58, N. Y., was announced by Fred F. Rochll, vice-president and general sales manager.

As a field representative, Mr. Trecot will call on industry in the north Detroit, Mich. area. He will be available for demonstrations of latest welding

Frank P. Trecot

techniques and materials, and for consultation services on shop problems.

Mr. Trecot was in the metal-working industry for eight years prior to joining "Eutectic."

Have you tried SEMI-AUTOMATIC HARD-FACING with STOODY WIRES?

Semi-automatic hard-facing is fast taking hold in all industry! Here's a process that *removes much of the labor of welding* and is 2 to 4 times *faster* than manual application. Weldors can see the weld —wires are fed bare; no submerging flux or flux dams are required. Welding is continuous, feeding from layer wound coils...no stub ends, no lost time changing electrodes. With higher speed there is lower heat input, less penetration of the base metal and reduced dilution of deposits...hence higher wear resistance than with manual electrodes of similar analysis.

WHAT CAN YOU HARD-FACE SEMI-AUTOMATICALLY?

Virtually all large parts now hard-faced manually ...crusher rolls, mill hammers, impact crusher rotors, shovel and tractor parts, tool joints, dredge pump impellers and casings, muller tires, etc.

ASK FOR DEMONSTRATION—Most Stoody distributors (check the yellow pages of your phone book) are equipped to demonstrate Stoody Semi-Automatic Hard-Facing *right on your job!* Ask your distributor to arrange a demonstration today!

STOODY SEMI-AUTOMATIC WIRES—Now available in 11 types for *maximum* wear resistance under *every* wear condition!

STOODY COMPANY
11986 East Slauson Avenue
Whittier, California

For more details, circle No. 24 on Reader Information Card

JOIN THE SWING TO HI-AMP®

Yes, the swing is on and here's why:

- 30% More Heat Resistant than any other make.
- Brilliant Red and Yellow Glass Fibre Colors insures identification of Holder anywhere in plant—Valuable Safety Feature.
- Low initial cost, easy and economical to maintain.

Sold only through Welding Supply Distributors throughout the U.S. and Canada.

LENCO, Inc.

Circle No. 25 on Reader Information Card

Kropp and Kosty Named by Eutectic

According to recent announcements from Eutectic Welding Alloys Corp., Flushing 58, N. Y., William H. Kropp and Graham J. Kosty have been assigned as district engineers by the company.

Mr. Kropp, as a field representative will service local industry in the Roch-

William H. Kropp

Graham J. Kosty

ester, N. Y. area. He is a member of the AMERICAN WELDING SOCIETY.

Mr. Kosty has been assigned to service eastern Alameda and San Joaquin counties in California.

Webber Joins Harper Electric Furnace

H. M. Webber has been appointed manager of Process Engineering for Harper Electric Furnace Corp., 39 River St., Buffalo 2, N. Y., Roderick L. Harper, executive vice-president, announced today.

As a part of his process engineering responsibilities, Mr. Webber will direct an expanded program for the development and promotion of the Harper line of continuous brazing and sintering furnaces.

H. M. Webber

A graduate of the University of Colorado with a B.S. degree in Electrical Engineering, Mr. Webber has been an application and process specialist with the Industrial Heating Department of the General Electric Co. for the past 30 years.

Mr. Webber is co-author of the book "Protective Atmospheres" and is the author of over 80 articles and papers on furnace brazing, sintering, bright annealing and protective atmospheres.

Mr. Webber is a member of the AMERICAN WELDING SOCIETY, the American Society for Metals, the Metal Powder Association, Tau Beta Pi and Eta Kappa Nu.

OBITUARY

Herbert H. Hose

Herbert H. Hose, 54, died of a heart attack while on vacation at Arbor Vitae, Wis. on Sept. 24, 1957. He was a welding engineer for Ampco Metal, Inc. where he had been employed for the past fourteen years. Prior to his employment with Ampco, he worked for the welding division of the Harnischfeger Corp. in several capacities. He had been a member of the AMERICAN WELDING SOCIETY for many years.

EMPLOYMENT SERVICE BULLETIN

Position Vacant

V-350. Electrode coating research chemist. Leading manufacturer of welding electrodes is expanding its Research and Development Department.

Interesting position is available requiring experience in metallurgy, chemical analysis and/or coating formulation.

Excellent facilities, stimulating and congenial atmosphere; fine opportunity for right person. He should take an intense interest in his work and be able to get along with people.

Send full résumé, including salary requirements.

Services Available

A-700. Welding engineer pipe line superintendent. Metallurgical background. Fifteen years supervisory experience in plate fabrication shop, power plant and refinery construction. Had charge of physical testing and radiographic inspection. Will accept two years foreign assignment. In excellent health.

Weldynamics*

*** ARC WELDING AT WORK CUTTING COSTS**

HOW YOUR NEXT JOB WILL BE HANDLED FOR LESS COST

For lowest cost, Weldynamics indicates that both AC & DC welding currents are needed to take full advantage of today's high-speed electrodes. One machine, Idealarc, fills this need . . . does the work of two welders. As a result, you need fewer machines, work scheduling is simplified, there are fewer machines standing idle.

Lincoln men, trained in Weldynamics, will show you how to apply these cost cutting advantages to your specific jobs—with the latest methods and electrodes available today.

Idealarc 180, 250, 300, 400 and 500 amp sizes. Available as AC or AC/DC welder. Can be purchased with AC only, adding DC later. Operates on single phase power. Write for Bulletins SB-1364 and SB-1343.

The World's Largest Manufacturer of Arc Welding Equipment

LINCOLN

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THE LINCOLN ELECTRIC COMPANY, DEPT. 1936, CLEVELAND 17, OHIO

For more details, circle No. 26 on Reader Information Card

NEW LITERATURE

AWS Includes Aluminum-Bronze Wires in New Copper Specification

For the first time two types of stranded aluminum-bronze electrodes (ECuQl-A2 and ECuAl-B) are covered by a specification. In addition, one type of aluminum-bronze electrode (ECuA1-A2) for use with the submerged arc process, is standardized.

AWS and ASTM have just issued a new specification for Copper and Copper-Alloy Arc-Welding Electrodes (AWS A5.6; ASTM B225). These electrodes are for use with the shielded metal-arc, inert-gas metal-arc (consumable electrode) and submerged-arc welding processes.

The eight classifications in this edition include copper, copper-silicon, copper-tin, copper-nickel and copper-aluminum electrodes. Chemical composition, mechanical properties and usability characteristics of each classification are given together with tests for verifying these properties.

An appendix is included as an aid to users in selecting the best electrode for their needs and using it in the most efficient way. It provides information on the use of each filler metal for joining different base metals with the different welding processes.

Copies of the Specification can be obtained at 40 cents each from the AMERICAN SOCIETY, 33 W. 39th St., New York 18, N. Y., or from ASTM, 1916 Race St., Philadelphia 3, Pa.

Safety

The safe use of abrasives is discussed in Data Sheet D-452, "Coated Abrasives." Prepared and reviewed by safety engineers, it is one of several published periodically by the National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

For your free copy, circle No. 27 on Reader Information Card.

Consumable Inserts

A new 12-page booklet from Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa., shows how to make a quality root pass with a consumable insert when only one side of the weld is accessible.

The booklet compares conventional methods of producing a root pass to the use of consumable EB weld inserts. Fifteen different insert compositions are classified for the welding of carbon steels, austenitic stainless steels, nonferrous alloys and chrome-moly and chrome steels.

One section deals with joint design for varying wall thickness. Placement of the EB weld insert for a typical butt weld is diagramed. A chart lists recommended filler rods. Also included are data on the dimensions of welded and seamless steel pipe and specifications for austenitic stainless-steel pipe of both welded and seamless versions.

For your free copy, circle No. 28 on Reader Information Card.

Audio-Visual Aids

Now available from Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y., is a new publications and audio-visual list.

The publications cover various applications of industrial gases, and welding and cutting techniques and equipment.

The motion pictures, for showing to audiences represented by companies, schools, business groups and other interested organizations, depict the latest developments in automatic welding, machine gas cutting and other processes and products. A selection of sound slide films is offered to help teach students, welders, technicians and foremen the operation, proper maintenance and safe use of modern welding and cutting equipment.

For your free copy, circle No. 29 on Reader Information Card.

Nickelsworth

Volume XXIII, No. 2 of "Nickelsworth," a publication of the International Nickel Co., Inc., 67 Wall St., New York 5, N. Y., is now available. Included in the 8-page pamphlet is an article which describes a welded vacuum furnace, fabricated from Inconel, at North American Aviation. Another article discusses Elano Corp.'s use of an Inconel filler wire in the welding of AEC's pumps.

For your free copy, circle No. 30 on Reader Information Card.

Positioning Aids

Aronson Machine Co., Arcade, N. Y., have new literature available which describes their new "Twinner Magneto Clamps," aids used in setting up welding work. The clamps can be used either singly or in groups for setting up on the welding table itself or for holding work pieces in position. According to Aronson, the clamps are powerful enough to hold work for tacking and yet easily removed when the job is finished.

For your free copy, circle No. 31 on Reader Information Card.

AWS Bibliographies Available

A comprehensive set of bibliographies of articles which have appeared in the Welding Journal during the last 20 years and covering practically every welding process, metal and material has been prepared by the AMERICAN WELDING SOCIETY. This set of bibliographies is one of the most exhaustive available. Articles are grouped under 28 headings which include such industries as aircraft, railroads and shipbuilding; processes such as brazing, oxygen cutting, resistance welding, inert-gas metal-arc welding and submerged-arc welding; and metals such as aluminum, cast iron, copper, stainless steel, molybdenum and zirconium.

Listings begin as far back as 1937. All articles on a particular subject are listed during the year they appeared.

These bibliographies of welding articles, covering a period from 1937 through December 1957, will be invaluable to all who require background information on welding. Research men will save days of searching through libraries and technical literature for authoritative information.

The set of 28 bibliographies, enclosed in an attractive binder, lists for $5.00; single bibliographies 50c. Available from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York 18, N. Y.

Cutting Machines

An 8-page descriptive folder from the American Messer Corp., 405 Lexington Ave., New York 17, N. Y., lists the various types of cutting machines which they manufacture. Included in the illustrated brochure are such special cutting machines as Corta 52, Statosec, Statosec "SW," Sine-Cosine, Billet and Portal.

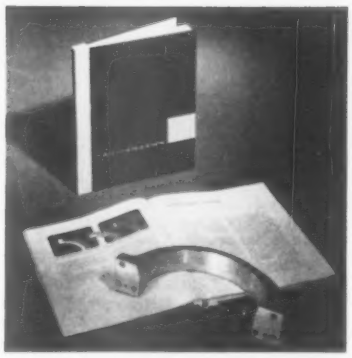
For your free copy, circle No. 32 on Reader Information Card.

Radiography Handbook

The second edition of "Radiography in Modern Industry," a "handbook" of industrial radiography, has been issued by Eastman Kodak Co., Rochester 4, N. Y.

Of particular interest to those responsible for industrial radiographic inspection, the revised edition contains information on the sensitometric characteristics of Kodak films, new data on radioactive isotopes and their application, and a guide for the selection of appropriate Kodak films for both X-ray and gamma-ray radiography. There is also new material on image amplification, geometric enlargement and radiation monitoring.

Copies of the 40-page volume are



available at $5.00 list through Kodak X-ray dealers. Additional information may be obtained from dealers or by writing X-Ray Division, Eastman Kodak Co., Rochester 4, N. Y.

Resistance-Welding Control

Bulletin GET-2683, 12 pages, from General Electric Co., Schenectady 5, N. Y., furnishes electrical and mechanical information on standard components comprising non-synchronous welding control to assist users in selecting proper equipment to meet particular application requirements and determine necessary electrical interconnections. The bulletin is illustrated by 18 diagrams, charts and schematic drawings.

For your free copy, circle No. 33 on Reader Information Card.

Safety Catalog

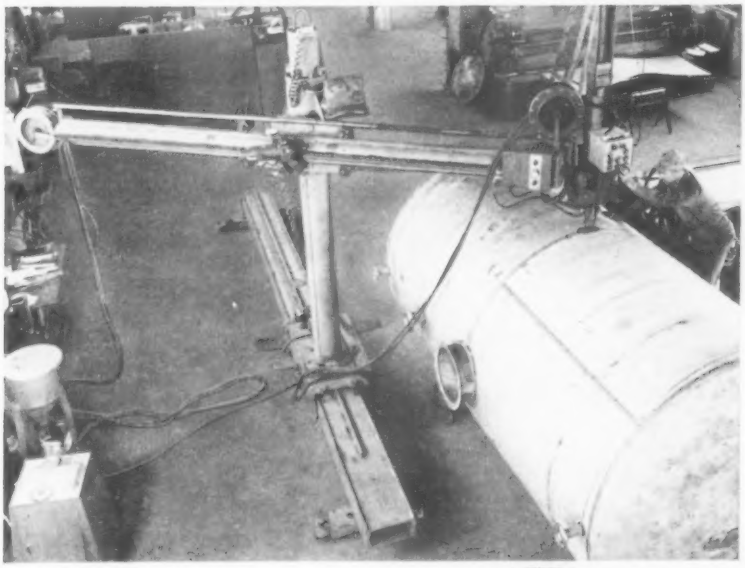
Sellstrom Manufacturing Co., Palatine, Ill. announces the availability of a new catalog. Featuring the complete line of "Sellstrom Safeguards," face and eye protection equipment, the 28-page brochure illustrates and describes

such products as goggles, glasses, lenses, welding helmets, hand and face shields and respirators.

For your free copy, circle No. 34 on Reader Information Card.

Lower the boom on welding costs!

with LEWIS AUTOMATIC WELDING HEAD MANIPULATORS



Designed and manufactured by a weldment fabricator, the LEWIS line of manipulators is *functionally engineered* for profitable automatic welding. Three classes of precision machines are available to meet diversified production requirements.

The BANTAM Series . . . new, portable, pedestal-base manipulators designed for weld seams and working heights up to 8 ft. These lightweight machines pilot fully-automatic heads . . . feature 360° boom rotation.

The UNIVERSAL Series . . . versatile, portable, fully-adjustable manipulators that provide boom travel and working heights up to 12 ft. Available with track or pedestal type bases and a variety of precision control systems.

The HEAVY DUTY Series . . . large car-type units for floor rail installations. Boom travel and working heights range up to 24 ft. Power source and auxiliary equipment carriage-mounted. Also available with operator's station at boom tip.

ENGINEERS • DESIGNERS
FABRICATORS • MACHINISTS

LEWIS

FOR DETAILS AND SPECIFICATIONS, WRITE FOR NEW BULLETIN 7703.

7901-LWE

109 NORTHFIELD ROAD • BEDFORD, OHIO

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Announcing

1958 P&H WELDER LINE

with *Dial-lectric* remote control

—industry's finest precision amperage control.

P&H Dial-lectric—can be varied while welding . . . by remote control 50 feet away, if necessary! Machines can be installed off-the-floor, yet operators can change heats at the work!

Wave balance—provides stable, equal sine wave, eliminates clipping, balances cleaning and welding portions of cycle in welding light metals. Cleaning action increases, weld coalescence improves considerably.

High-frequency controls—phase-shift rheostat minimizes chopping and improves arc-starting. Intensity rheostat stabilizes arc intensity over entire operating range in critical aluminum, magnesium, and stainless steel welding.

- Designed to provide new high standards of operating efficiency
- Ranges from 3 to 675 amps in AC, DC, and AC-DC models
- Built-in high frequency, gas, and water controls
- Good looking, simple construction, easy to service
- Built for easy operation and positive control
- Safety construction prevents accidents . . . conforms to all NEMA safety standards

If you'd like additional specification data or a detailed description of any type welding machine in the new P&H line, write Dept. 307U, Harnischfeger Corp., Milwaukee 46, Wisconsin.

HARNISCHFEGER

P&H WELDERS • ELECTRODES • POSITIONERS

MILWAUKEE 46, WISCONSIN

For more details, circle No. 36 on Reader Information Card

The new P&H AC-DC Welder —
one of 23 *new* AC, DC, and AC-DC models
with intermediate ranges from 3 to 675 amps. Available with
or without built-in high-frequency, gas, and water controls.

For more details, circle No. 36 on Reader Information Card

Flame-Cutting Nozzles

The story behind the manufacture of Oxweld flame-cutting nozzles is told in a new 12-page folder prepared by Linde Company, Division of Union Carbide Corporation, 30 E. 42nd St., New York 17, N. Y. The new folder, form 1024, describes and illustrates some of the many production steps that go into the manufacture of Oxweld cutting nozzles, and also tells how precision workmanship at the factory in the production of cutting nozzles assures dependable performance and efficient operation on the job.

For your free copy, circle No. 37 on Reader Information Card.

High-Temperature Brazing

A new single-sheet 8½- x 11-in. two-color engineering page (Number 17) discussing Nicrobraz flux for high-temperature brazing application is now available from Stainless Processing Division, Wall Colmonoy Corporation, 19345 John R Street, Detroit 3, Mich.

The new data sheet describes the properties and uses of Nicrobraz flux. One section is devoted to a brief description of application techniques.

For your free copy, circle No. 38 on Reader Information Card.

Hard-Surfacing Selector Guide

Rankin Manufacturing Company, 616 S. Marengo, Alhambra, Calif., manufacturers of hard-surfacing materials, announce the availability of a pocket-size "Select-o-graph Guide" for use in the proper selection of Rainite rods.

Basic information concerning such rod characteristics as polarity, sizes, position information and hardness, appears on the inside of the folded flap. The guide also makes use of a color code designed to identify the seven different types of Rainite rods with the applications to which they are best suited.

For your free copy of the guide, circle No. 39 on Reader Information Card.

Safety Slogans

A flyer containing over 1000 safety slogans is available from the National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

For your free copy, circle No. 40 on Reader Information Card.

Press Welder Guide

A 6-page bulletin on precision spot and projection press welders is available from the Precision Welder and Flexopress Corp., 3520 Ibsen Ave., Cincinnati 9, Ohio. Listed are specifications for the entire line which includes resistance welders from 30 to 600 kva, 1275- to 18,000-lb electrode forces, 12- to 30-in. throat depth. Bulletin P-101 contains a variety of air cylinder and electrode arrangements. Many optional features and major product features are also illustrated and described, along with examples of special tooling.

For your free copy, circle No. 41 on Reader Information Card.

Stainless Steel

A new 4-page bulletin from Armco Steel Corp., 2557 Curtis St., Middletown, Ohio, describes briefly the properties of 17-4 PH and 17-7 PH stainless steels. Corrosion resistance, high strength, workability and hardenability at low heat-treating temperatures are some of the points brought out. Typical applications are listed.

For your free copy, circle No. 42 on Reader Information Card.

Aluminum

A technical booklet on the use of aluminum for tanks and vessels is now available from Reynolds Metals Co., 2500 S. 3rd St., Louisville, Ky.

The booklet is said to serve as a basic technical guide to design, fabrication and applications of aluminum tanks and vessels. It lists more than 100 general types of chemicals for which aluminum applications are particularly advantageous.

For your free copy, circle No. 43 on Reader Information Card.

Induction Heating

Copies of bulletin, 12B8513, are available from Allis-Chalmers Manufacturing Co., Milwaukee 1, Wis., which features high-frequency motor-generator induction-heating equipment applicable for low cost brazing, annealing, deep hardening, forging and melting.

Included in the bulletin is a description of 960, 3000 and 10,000-cycle high-frequency motor-generator units available in sizes from 30 to 1250 kw.

For your free copy, circle No. 44 on Reader Information Card.

Steel Weight Finder

The "Steel Weight Finder," an instrument designed and developed for the steel industry by the Alcott Calculator Co., P. O. Box 4606, Ft. Lauderdale, Fla., reportedly enables the user to determine quickly and accurately the

exact weight of a wide variety of steel products. There are over 1000 items contained on this compact slide chart, including steel angles, beams, channels, flats, rounds, squares, hexagons and strips. Also given are the weights of steel sheets (HR, CR and Galvanized), smooth plate, floor plate, concrete reinforcing bars and pipe.

To receive your free copy of an illustrated brochure on this product, circle No. 45 on Reader Information Card.

Automatic Welding

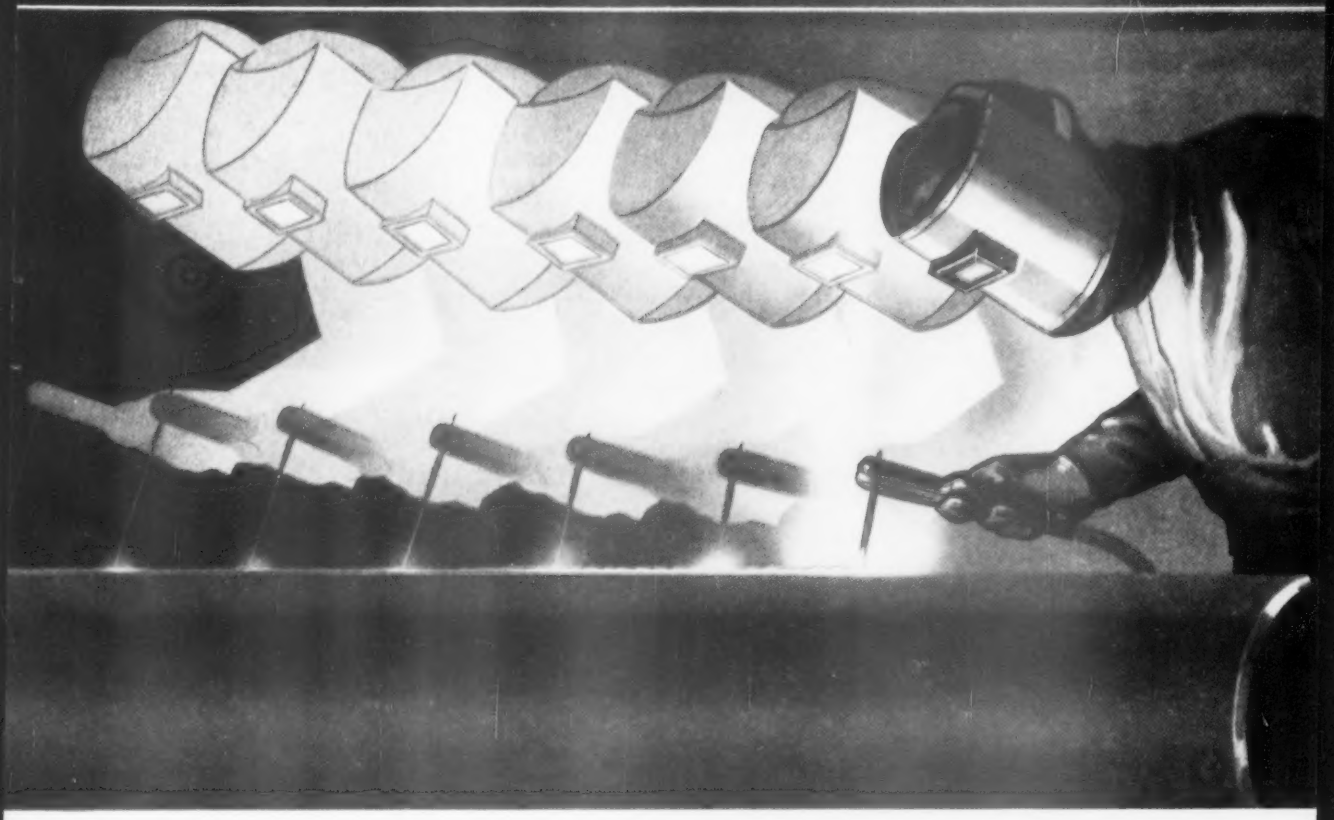
A new illustrated brochure devoted to automatic welding machines has been published by Dix Engineering Co., Inc., Lincoln Park, Mich.

The two-color brochure highlights a number of distinct problems in welding automotive parts and describes solutions with custom designed and built Dixco automatic welders. Included are welding problems encountered in manufacturing automatic transmission, drive tube, rear quarter panel and bumper guard assemblies.

The photographs of automatic welding machines built by Dix for these special jobs are accompanied by brief case histories, along with a complete explanation of the company's research and development services.

For your free copy, circle No. 46 on Reader Information Card.

NEW MUREX® IRON POWDER "Hot Rod"



SPEEDEX TRIPLEX

another NEW product

matches deposit rates of automatic welding..

Manual welding speeds as much as 40% faster than competing electrodes—deposit rates up to 16 lbs. of weld metal an hour—have been obtained in actual tests with TRIPLEX, the new Murex iron powder electrode. Designed for high speed downhand welding with either drag or open arc technique, it produces X-ray quality welds with ultimate strengths of 62,000 to 66,000 psi and elongations of 30 to 33%.

SPEEDEX TRIPLEX offers all the usual advantages of iron powder electrodes. It has good arc characteristics and an easily removed slag. In addition it operates equally well on AC or DC and, in the ¼" diameter, at currents up to 450 amps. It is by far the fastest of the MUREX SPEEDEX line and is especially suited to the welding of large fabrications such as ship sections, freight cars, machine frames and pressure vessels.

Write for specific information on SPEEDEX TRIPLEX. Ask, too, for Folder IP-57 describing the entire SPEEDEX iron powder line.

METAL & THERMIT CORPORATION
Rahway, New Jersey

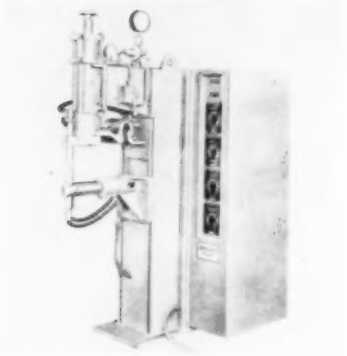
For more details, circle No. 47 on Reader Information Card

NEW PRODUCTS

Spot-Welding Machine

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., announce the new design of a standard, air operated, press type, low impedance, single phase, SP 1 spot welder designed to cover a wide range of commercial welding applications.

The SP 1 will reportedly effect high-



quality welds on small or large production runs on a wide range of industrial metals. This welder is number one in a series of frame sizes ranging from 1 SP through 5 SP. Available in 30, 50 and 75 kva at 50% duty cycle, the 1 SP can be furnished with either 18-, 24-, 30-, 36- and 42-in. throat depths.

According to Sciaky, electrode force up to 1575 lb is provided at 80-psi line pressure.

For more details, circle No. 48 on Reader Information Card.

Inert-Gas Water Supply

Hobart Brothers Co., Troy, Ohio, has developed a "complete package" outfit that reportedly makes it independent of water lines during inert-gas welding.

A Hobart a-c d-c inert-gas-shielded

arc welder is combined with a "circoolator" (water tank with motor driven pump). According to Hobart, this combination, which also provides the rack for inert-gas cylinders on which the torch, hose and cables may be draped, saves time by letting the operator change inert-gas welding stations without installing water lines or changing hose connections.

For more details, circle No. 49 on Reader Information Card.

Brazing Flux

A larger size of its "Jet Flux" automatic fluxing system and an improved metering valve assembly, which is reportedly interchangeable on all models and sizes, is announced by All-State Welding Alloys Co., Inc., 249-55 Ferris Ave., White Plains, N. Y.

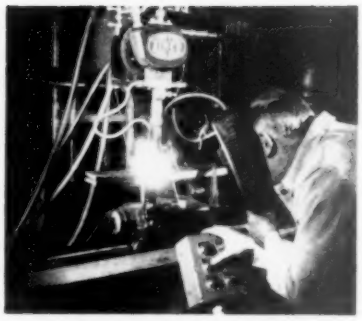
The system is used in production and maintenance brazing operations employing the oxyacetylene welding torch. It consists of an automatic unit which, installed in the acetylene line, proportions "Jet Flux" brazing liquid to the flow of fuel gas and mixes them.

Automatic fluxers of this type heretofore available have been limited in capacity to a half-gallon of "Jet Flux" liquid. The new "Jumbo Jet Tank" holds a full gallon.

For more details, circle No. 50 on Reader Information Card.

Automatic Inert-Gas Welding

The new heavy-duty inert-gas-shielded metal-arc machine head developed by Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 150 E. 42 Street, New York 17, N. Y., is specifically designed for the heavier, production applications of automatic machine welding.



Outstanding feature of the new Model AMH-C unit is its capacity for heavy welding wires. According to Airco, aluminum wires of from $\frac{3}{64}$ to 18 in. and hard wires from 0.045 to $\frac{1}{4}$ in. can be fed at any rate up to 600 ipm. Wire feed speed is said to be fully adjustable by means of a calibrated governor which regulates the $\frac{1}{3}$-hp wire-drive motor.

The AMH-C machine barrel is rated at 600 amp on a 100% duty cycle.

The welding head can be rotated through 360 deg for work in virtually any position.

For more details, circle No. 51 on Reader Information Card.

Welding Positioner

Harnischfeger Corporation, Milwaukee 46, Wis., recently unveiled its WP-80 welding positioner at a four-day Welder Division sales conference in Milwaukee.

Termed by P&H officials as the largest welding positioner in the world, the unit is reportedly capable of manipulating and positioning weldments up to 80,000 lb. This rapid feature enables the welding operator to weld in the more "natural" downhand position. Fabricating time is said to be reduced by as much as 50%.

Available with either single- or two-speed table rotation, the WP-80 positioner can rotate workpieces through 360 deg from 0.0135 rpm to 0.31 rpm, elevate and lower 5 ft and tilt 135 deg. It is also reported that counterweights are not necessary on this model.

For more details, circle No. 52 on Reader Information Card.

Iron-Powder Electrode

Air Reduction Sales Co., Division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y., has announced a new mild-steel iron-powder type electrode, designated as Airco Easyare 30, that is said to deposit metal at the rate of 17 lb per hour (100% work factor). This rate of deposition is reportedly the fastest ever approached by a "stick" electrode and is accomplished through the use of an extra-heavy iron-powder coating together with increased machine settings.

According to Airco, mechanical properties of the deposits are comparable to or better than AWS E6020-30 classifications. The steady spray-type transfer and the deep shield maintained, permit flexibility of arc length to accommodate various welding techniques.

For more details, circle No. 53 on Reader Information Card.

X-Ray

A new Norelco projection microradiograph, designed for X-ray microscope techniques is available from the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

The unit employs an X-ray source approximately one micron in size to produce enlarged images of specimens placed close to the radiating surface.

Contrast is controlled to some extent by varying the accelerating potential of the electron beam and by changing target materials.

The electron-optical system includes an electron gun, high-voltage source for electron acceleration, electro-magnetic lenses to control beam size and con-

BERNARD

"Shortstub"

ELECTRODE HOLDERS

ONE TON PRESSURE CONTACT provides peak conductance from the holder to the electrode.
HIGH WELDING CURRENT CONDUCTANCE assured through aluminum-copper alloy head.
SPECIAL EXTRUDED COPPER-ALLOY body with large cross-sectional area.
TWO CABLE CONNECTING SCREWS by alternate tightening develop a 1400 lb. tightness between cable and holder.
LIFEGUARD INSULATION developed after many years to resist heat, shock, impact and outwear all other types 3 to 1.
ENTIRELY INSULATED from end to end, assuring complete safety from electric shock.
CABLE-SPLINT FEATURE entirely eliminates loss of conductance by protecting the cable against fraying.
CABLE SPLINT PAT. PEND.

unequalled for

- EFFICIENCY
- ECONOMY
- SAFETY
- DURABILITY

IN HIGH CURRENT - HIGH SPEED WELDING

PIONEER FOR BERNARD MODERN WELDING

SOLD THRU LEADING DISTRIBUTORS THRUOUT THE WORLD

BERNARD WELDING EQUIPMENT COMPANY
10232 AVENUE N, CHICAGO 17, ILLINOIS

For more details, circle No. 54 on Reader Information Card

figuration and targets having surface planes normal to the beam at the end of its path.

X-rays are produced when targets are struck by the electron beam. Since the specimen is adjacent to the target, enlargement depends on the ratio of distances measured from X-ray source to film and specimen, respectively.

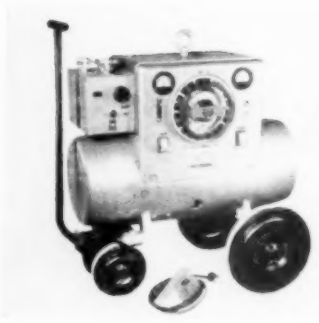
The manufacturer states that the new instrument permits critical evaluation of opaque specimens and is an aid in light and electron microscope work. Stereo micrography, absorption analysis, change of target materials during operation and choice of vacuum or air in the specimen chamber are features of the new unit which permit routine handling of difficult problems.

The complete assembly includes a kv meter, kv controls, beam control with variable bias, vacuum indicator, fine and coarse control for the condenser lens, and coarse, medium and fine controls for the objective lens.

For more details, circle No. 55 on Reader Information Card.

Tungsten-Arc Welding

A new inert-gas tungsten-arc welding attachment for factory installation only



on Hobart motor-generator arc welders is being announced by Hobart Bros. Co., Troy, Ohio.

According to Hobart officials, the unit is designed for critical inert-gas tungsten-arc welding applications where extremely low ripple (1% to 2%) d-c welding current is required to weld such metals as stainless steel, high carbon steel, cast iron, silicon bronze, deoxidized copper and silver.

The high frequency unit, complete with gas and water valves, is neatly mounted at the left of the welder control panel.

For more details, circle No. 56 on Reader Information Card.

Stud Welding

A new small stud welding gun, which reportedly weighs one-third less than any unit previously marketed and designed to weld studs faster and more reliably, has been introduced by the Nelson Stud Welding Division of Gregory Industries, Inc., Lorain, Ohio.

The manufacturer reports that the

Nelson NS-10 is so balanced that it is as easy to handle as a hammer. Despite its small size, this gun will weld all studs up through 1/2 in. in diam. The gun weighs less than four lb and measures only 9 in. in length.

The NS-10 uses the regular Nelson line of studs, ferrules and welding accessories.

For more details, circle No. 58 on Reader Information Card.

ACRO WELDER MFG. CO.

MILWAUKEE

WELDING ENGINEERS

MACHINERY BUILDERS

WELDING MACHINERY ENGINEERED AND MANUFACTURED TO ORDER AND SKILLFULLY AUTOMATED TO MEET INDUSTRY'S MOST EXACTING AND RAPIDLY CHANGING PRODUCTION TOOLING REQUIREMENTS

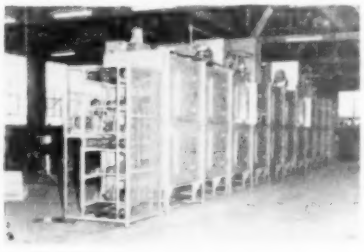
EXPERIENCE - INGENUITY - INTEGRITY

ESTABLISHED 1936

For more details, circle No. 57 on Reader Information Card

Conveyor Oven

Steiner-Ives Co., Springfield Rd., Union, N. J. has introduced a new conveyor oven designed to bake special flux coatings on various diameter and length welding rods for a large midwest



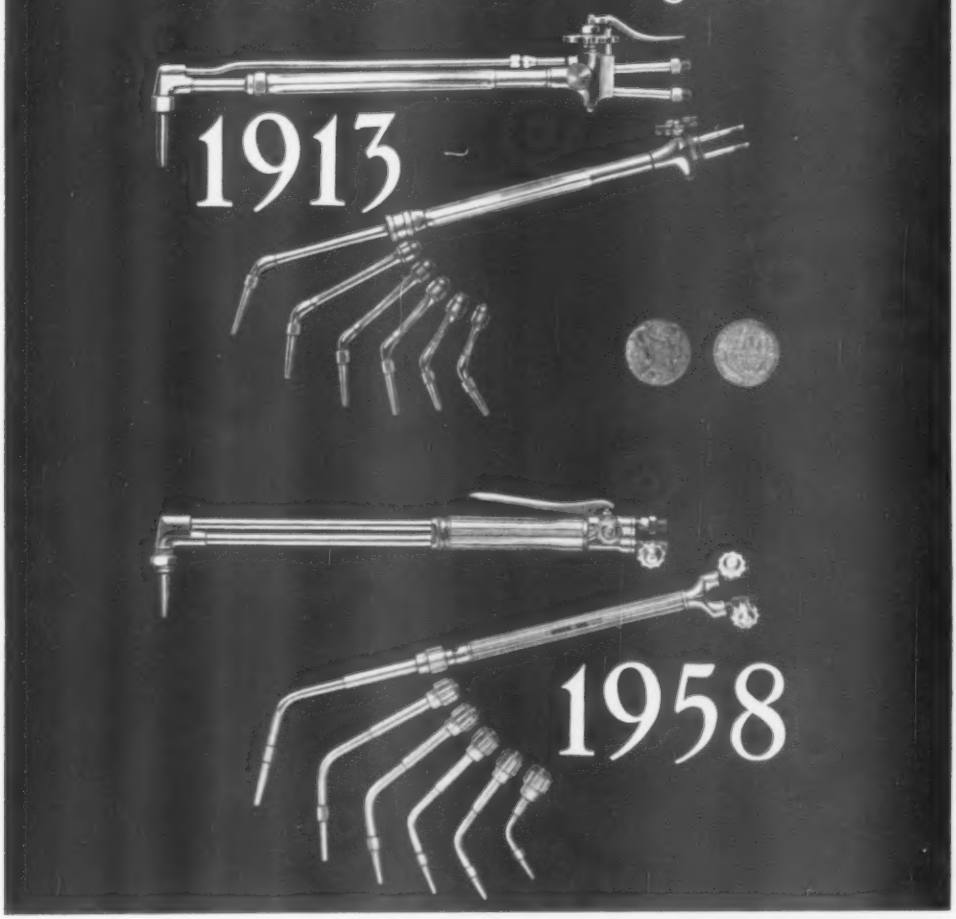
manufacturer. Recent changes in rod alloy have caused additional, higher than previous, oven temperatures to be required.

Unit embodies two independently operated gas fired ovens for operation to 1000° F. Ovens have two passes each and a 5th pass for cooling before packaging.

For more details, circle No. 59 on Reader Information Card.

VICTOR EQUIPMENT COMPANY

45 Years of Progress



QUALITY . . . SERVICE

VICTOR for welding

the original Victor welding and cutting torches were created in 1913 to fill the need for better and safer equipment—torches that were practical, versatile and built to last—created to be a victor in the field.

Victor torches were an immediate success—they were designed with the user in mind by L.W. Stettner, a skilled and experienced pioneer welder who knew the needs of the men who work with torches—the design was so efficient and well thought out that few changes have been made since that time.

Victor safety regulators were created in the same pattern—to fill the need for safe, reliable, and practical equipment for the man in the field.

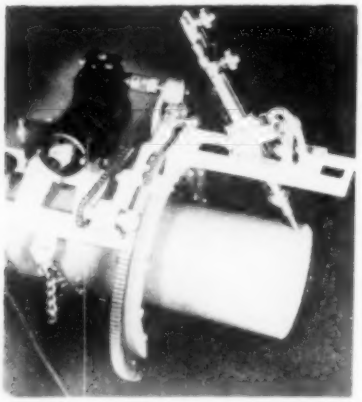
the success and popularity of Victor today is solidly based on the application of those principles under active leadership of the original inventor and founder.

VICTOR EQUIPMENT COMPANY *SAN FRANCISCO LOS ANGELES CHICAGO*

For more details, circle No. 60 on Reader Information Card

Pipe Beveling Machine

The H&M Pipe Beveling Machine Co. of Tulsa, Okla., has announced production of a motorized machine. The H&M motorized unit reportedly provides automatic operation in cutting



and beveling on pipe, ranging in size from 1½ to 36 in. This unit can be attached to any one of H&M's seven standard machines.

The motorized-unit attachment is powered by a fractional hp a-c, d-c electric motor that is affixed to the machine by means of a mounting bracket. To switch from manual to automatic, a flexible coupling is used to connect the motor with the crank pinion, which drives the main gear and the cutting torch around the pipe.

According to the manufacturer, the operation of the motorized unit is accomplished by setting the governor-controlled motor to the required speed and turning the switch to the direction of travel that is desired.

For more details, circle No. 61 on Reader Information Card.

Electrode Holder

Announcement of a new electrode holder has been made by Duro Engineering Co., 51 Oregon Ave., Hamden, Conn.

The electrode holder, known as the "Durogon," is available in two models, N3 and N3HD. Model N3 will take a maximum current of 300 amp, holds electrodes from 1/16 through 1/4 in. diam and weighs 14 oz. Model N3HD has similar characteristics but, due to its 22-oz weight, is recommended for "heavy duty" service. The lighter model is made of aluminum with the exception of copper alloy jaws, while the heavier model is made of bronze.

For more details, circle No. 62 on Reader Information Card.

ANY Pipe Joint or Structural Angle Cut NOW Layed Out in Just MINUTES!

- Marks off easily and accurately any pipe joint.
- Eliminates all figuring of cut backs, and marks all around pipe.
- Saves man-hours, as well as oxygen and acetylene gas.
- Makes it easy to mark off end of lateral pipe.

NO MISTAKES — NO TIME LOSS

—regardless of the type or size of pipe joint to be welded. No more "cut and try" with a **CONTOUR MARKER** — it eliminates the need for calculation, and is available in 2 sizes for marking pipe and structurals of 1½" to 18" in cross section, and from 16" to 48" diameter. Send for complete description.

CONTOUR MARKER CORP.
1843 E. Compton Bl., Compton, Cal.
Also Mfgrs. of Boyce Centering Heads, Radius Markers and Pipe Flange Aligners.

THE CONTOUR MARKER

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for the EXPERT...
the BEST...
MANGANAL
11%-13½%
MANGANESE-NICKEL STEEL
BARE WELDING ELECTRODES
TOP WELDERS CHOOSE MANGANAL BARE because:
1. It makes the strongest welds fastest.
2. No coating; no slag; no chipping.
3. Workhardens to 550 Brinell; tensile strength, 150,000 psi.
4. 100% metal deposit; every ounce counts.
For the most effective and economical reclamation welding of parts worn through impact and abrasion.
MEMBER
SOLE PRODUCERS
STULZ-SICKLES CO.
PORT AVENUE at JULIA ST. ELIZABETH, NEW JERSEY
Write for complete details and nearest distributor.

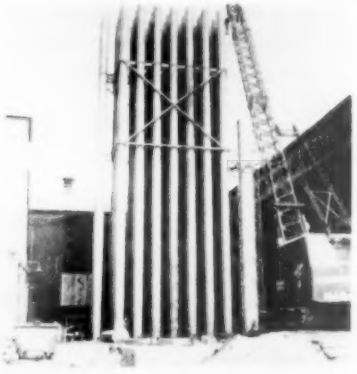
For more details, circle No. 63 on Reader Information Card

Oxygen Stored in Vertical Tubes

Vertical pressurized oxygen storage tubes, newcomers in the steel industry, have been installed by Air Products, Inc., for Granite City Steel Co. at Granite City, Ill.

Towering 80 ft above the ground, the 30 tubes are being placed on Granite City site by the Allentown, Pa. company. The storage bank holds 125,000 standard cu ft of 99.5% purity oxygen, providing Granite City with reserve oxygen for peak periods.

Stored under 450-psi pressure, the oxygen is generated at the steel company's new 60,000,000 cu ft per month



For heavy plate to thinnest alloys

VICKERS Controlarc*

MAGNETIC AMPLIFIER DC WELDER... AND ACCESSORIES

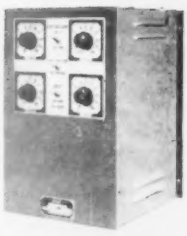
- Maintains arc stability through the complete current range from extremely low to extremely high without range switches.
- Bends the volt-ampere curve to meet the particular welding job being done.
- Full-range automatic arc control in any welding position.
- Strikes an arc without the use of high frequency when using inert gas and tungsten on lowest currents.
- Exclusive, patented Magnetic Amplifier combines fine control with ruggedness and durability.
- Exclusive, *dual* remote control equipment available . . . provides close control of current and voltage range.
- Low spatter performance on special electrodes.

*TRADEMARK

Write for complete information on this equipment and for other high quality—high performance welding machines under development.

SLOPE CONTROLLER

for automatic tungsten inert gas welding; using Vickers standard *drooping* (not constant potential) output welding power source. Linear—static—exclusive design.



INERT GAS WELDING CONTROL UNIT

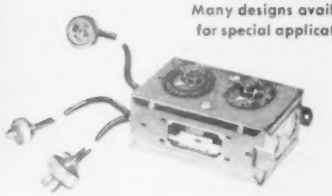
With or without timer adjustable pre-flow of inert gas and water.

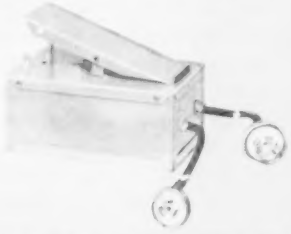
INERT GAS SPOT WELDING TIMER UNIT

for TIG guns which are high frequency started (Tungsten contact not required for initiation). Timer calibrated for 3 to 360 cycles.

REMOTE HAND AND FOOT CONTROLS

Many designs available for special applications.





CONSTANT POTENTIAL ADAPTER UNIT

Converts standard welder to constant potential power source for semi-automatic or automatic welding heads and guns.

CONSTANT POTENTIAL POWER UNITS

for automatic and semi-automatic production welding.

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

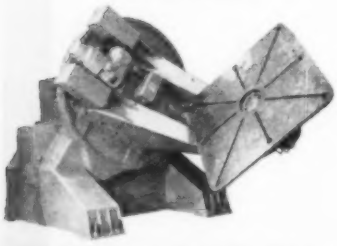
ELECTRIC PRODUCTS DIVISION

1853 LOCUST STREET • SAINT LOUIS 3, MISSOURI

For more details, circle No. 64 on Reader Information Card

something new from

BD



Berkeley–Davis

Special Cantilever

WELDING POSITIONER

The customer said, "We want to make two girth welds on a 10,000# piece at 90° without two setups." The job was done...engineered and produced by the world's finest manufacturer of welding machinery . . . Berkeley-Davis. Find out why Berkeley-Davis can make any standard or special positioner, regardless of size or shape . . . from the smallest to the largest, with a performance standard that can't be matched. Write today for your special or standard requirements.

BD

Berkeley–Davis Incorporated

DANVILLE, ILLINOIS

Associated with Federal Machine and Welder Co., Warren, Ohio

Circle No. 65 on Reader Information Card

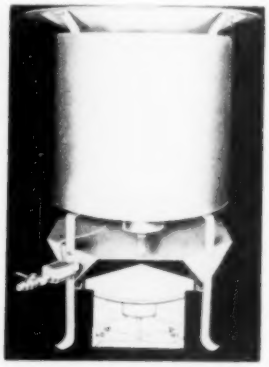
oxygen generator, leased from Air Products. Granite City also uses two smaller Air Products' units.

The vertical 80-ft tubes are "firsts" for the steel industry. Up to this time storage tubes have been installed horizontally. The new installation at Granite City requires only a fraction of the space necessary for a flat bank.

For more details, circle No. 66 on Reader Information Card.

Salamander

Weldit, Inc., 990 Oakman Blvd., Detroit 6, Mich., announces the availability of a variable-input "salamander" which uses a constant pressure. The



manufacturer states that positive heat control can be determined by a simple lever control which adjusts from maximum to minimum Btu output.

Called the Weldit "Heaterama," Model #1900, it is reportedly clean burning, producing no smoke or soot at any setting. The manufacturer further discloses that the unit is a single-burner "salamander" and is equipped with 100% automatic safety shutoff.

For more details, circle No. 67 on Reader Information Card.

Fume Exhaust

Designed to overcome the hazards of both toxic gases and arc flashes occurring during welding, the Series W-200-75 welding booths, developed and manufactured by Engwald Corp., 125 Sheridan Blvd., Inwood, L. I., N. Y., feature high velocity suction and durable steel side extensions.

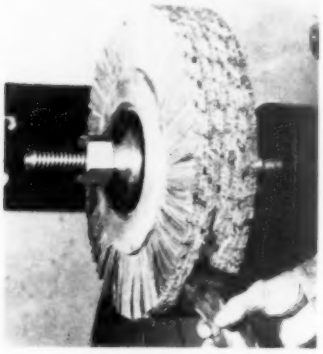
Sizes of booths vary: Height 30 to 42 in., width 30 to 60 in., depth 28 to 36 in. Appropriate Engwald blowers are available with air movement power of 400 to 1650 cfm.

The manufacturer states that all Engwald exhaust and fresh-air systems for industrial, safety and health applications are government-approved, and guaranteed for highest efficiency under the most rigorous tests.

For more details, circle No. 68 on Reader Information Card.

Abrasive Wheel

A new abrasive wheel composed of thousands of narrow finger-like abrasive strips, which produce a highly resilient brushing action, has been announced by the manufacturer, Merit Product Inc., 3691 Lenawee Ave., Los Angeles 16, Calif. According to Merit, the new



wheel exerts more exact control in working complex contours and curvatures without flatting or digging. The strips of abrasive flex to fit over and around changing contours. The wheel is reportedly useful in polishing, deburring and removal of surface flaws on all metals.

Sizes now offered include diameters of 14 and 16 in. with widths from 3 to 60 in. Selection of grits range from fine to coarse.

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Welding Chamber

A controlled-atmosphere welding chamber with a plexiglass dome has been developed by L & B Welding Equipment Co. of Berkeley, Calif.

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USS TECHNICAL WELDING DATA

1

Recommended practices for welding and gas-cutting USS "T-1" Steel

WELDING. You can metal-arc weld USS "T-1" Steel manually in the same way as hot-rolled structural carbon steels, but be sure to use low-hydrogen electrodes of the E9015-16 to E12015-16 classifications. These electrodes must be kept dry. You also can automatically weld this steel by the submerged-arc process and by the inert-gas-shielded metal-arc process. The "stringer bead" technique is the best to use.

Precautions when welding USS "T-1" Steel:

1. **Do not use cellulose-covered electrodes because of the danger of underbead cracking.**
2. **If the final weldment must be stress-relieved or otherwise heat-treated, do not use electrodes of the Nickel-Molybdenum-Vanadium type.**
3. **In general, do not preheat this steel. If preheating is necessary to improve the properties of the weld metal, don't let the preheat temperature go above 250 degrees F.**
4. **Whether or not you preheat, don't let the interpass temperature go above 250 degrees F.**
5. **Be careful to prevent local overheating if flame gouging is used.**
6. **In submerged-arc welding, don't let the heat input to the base metal be greater than that used with $\frac{5}{16}$" diameter manual electrodes.**

GAS-CUTTING. USS "T-1" Steel may be gas-cut as readily as structural carbon steel, using any of the commercial fuel gases now in use. Preheating is not necessary. You can soften the flame-cut edge to facilitate machining, if you desire. If you do, don't let the temperature of the flame-cut edge go above 1150 degrees F. This temperature should be measured by temperature-indicating crayons or other suitable means.

Precaution: Never gas-cut blooms, billets, bars or ingots of USS "T-1" which have not been quenched and tempered. They should be sawed or hot-sheared, or cold-sheared if the size permits.

QUALIFICATION OF WELDERS. In some cases, AWS-ASME Standard Qualification Procedure for testing welding operators is not suitable for USS "T-1" Steel. The standard $\frac{3}{4}$"-radius mandrel and guided bend jig force an elongation of about 20% in the extreme metal fiber. Since this is beyond the capacity of the high-yield-strength weld metal deposited by some electrodes used with USS "T-1" Steel, a welding operator should not be disqualified because of weld-metal characteristics not under his control. Consequently, the ASME Boiler Code permits, in certain cases, a larger $1\frac{1}{4}$"-radius mandrel for the qualification test.

REMEMBER THIS: In no other alloy plate steel would you find the combination of properties that "T-1" Steel possesses. Here, in just one steel, you get very high yield strength (90,000 psi minimum), extraordinary toughness, great resistance to impact abrasion, and good high temperature strength. These let you reduce the size of highly stressed parts . . . save weight, reduce the amount of welding required and cut your costs. USS "T-1" Steel is being used in bridge excavating equipment, pressure vessels, towers . . . in equipment that must take heavy abuse in sub-freezing temperatures . . . in equipment that must withstand heavy stresses and impact abrasion at temperatures as high as 600 degrees F.

Write For Complete Information about the application and fabrication of USS "T-1" Steel, United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

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A STUDY OF METALLURGICAL EFFECTS IN THE MULTIPASS WELDING OF ZIRCALOY

Tests made upon 32-pass Zircaloy weldment indicates that 100% joint efficiency can be achieved with very slight loss of ductility through proper control of interpass temperature

BY R. E. JOHNSON AND B. W. SCHAAF

ABSTRACT. From an engineering point of view, high-quality multipass welds are being made in Zircaloy. In confirmation of this, a 32-pass weldment was made and tested. These tests indicate that 100% joint efficiency was achieved with very slight loss of ductility through proper control of interpass temperature. Generally speaking, the corrosion behavior of the weldment is equivalent to, or better than, that of the base metal.

Hot-rolled plates of Zircaloy-2 and Zircaloy-3 were subjected to welding, then heat treated to exaggerate recognized embrittling phenomena and tested. These deleterious heat treatments caused property changes which appear to be worthy of consideration. It must be emphasized, however, that the metallurgical effects of these treatments are not the same as those produced by actual multipass-weld thermal cycles as has been postulated by other experimenters. The study of embrittlement of individual welds by furnace heat treatment has only pointed out the active variables; more work will be necessary to determine the degree of importance, if any, of such variables in multipass welding.

Introduction

The selection of materials for a nuclear reactor depends primarily upon availability, nuclear properties, corrosion resistance and mechanical properties. There is no material that satisfies completely all the requirements for a structural material in pressurized water reactors. However, zirconium-base alloys do possess an optimum combination of these properties. Zircaloy-2 and Zircaloy-3 are essentially sponge zirconium with small amounts of Sn and Fe (also Ni and Cr in Zircaloy-2) added to enhance corrosion resistance and mechanical properties. Corrosion resistance and mechanical shock considerations dictate the use of arc-welded, butt-joint fabrication wherever possible.

The Zircaloys are characterized by excellent weldability due to their low thermal conductivity, low thermal expansivity, apparently high fluidity in the liquid state, and small volume change on solidification.* However, ductile welds are achieved only when proper[1,2] precautions are taken to prevent atmospheric contamination during welding. The problem of uniformity of penetration (probably arising from the effect of evolved gases on the arc) cannot be denied.[3, 5, 4] However, the intent of this paper is to discuss metallurgical considerations.

The argument advanced by the authors is that although certain heat treatments can cause a loss of ductility in Zircaloy, such heat treatments are not obtained in multipass welding. The treatments which do occur do not produce changes warranting engineering concern. To confirm this argument, a multipass weldment was made and tested; also individual welds were made, treated and tested. Treatments were purposely chosen to impair the mechanical properties of base plate and weldments. A comparison of material so treated with material from a multipass weldment leads to the conclusion that multipass welding is not detrimental, since the properties of the weldment without further treatment are considerably better than those of the treated base material.

The scope of this paper is:

1. To present data on a 2¼-in. thick weldment to illustrate the results of proper welding technique on Zircaloy-2.
2. To present data on weldments in ⅛-and ¼-in. plate of the same Zircaloy, but subjected to special heat treatments designed to accentuate a loss of ductility.
3. To present data on weldments in ⅛-in. thick Zircaloy-3 plate subjected to special deleterious heat treatments.
4. To discuss conclusions based on the comparison of the above data.

For convenience of presentation, these four objectives will be referred to as phases of work in the body of this paper.

It is the opinion of the authors that insufficient knowledge exists at this time to describe quantitatively the mechanism of the active metallurgical phenomena. It is their hope that this paper will illustrate the excellent integrity of weldments in thick Zircaloy

R. E. Johnson is Associate Engineer and B. W. Schaaf is Engineer, Westinghouse Electric Corp., Bettis Atomic Power Div., Pittsburgh, Pa.

Alternate paper for 1958 AWS National Spring Meeting to be held in St. Louis, Mo., April 14-18.

* Thermal conductivity (Zircaloy-2) at 20° C: 6.8 Btu/hr/ft²/° F/ft. Coefficient of thermal expansion (Zircaloy-2) at 20° C: 6.5 x 10⁻⁶/° C. Volume change on solidification (Zircaloy-2): 1.5%.

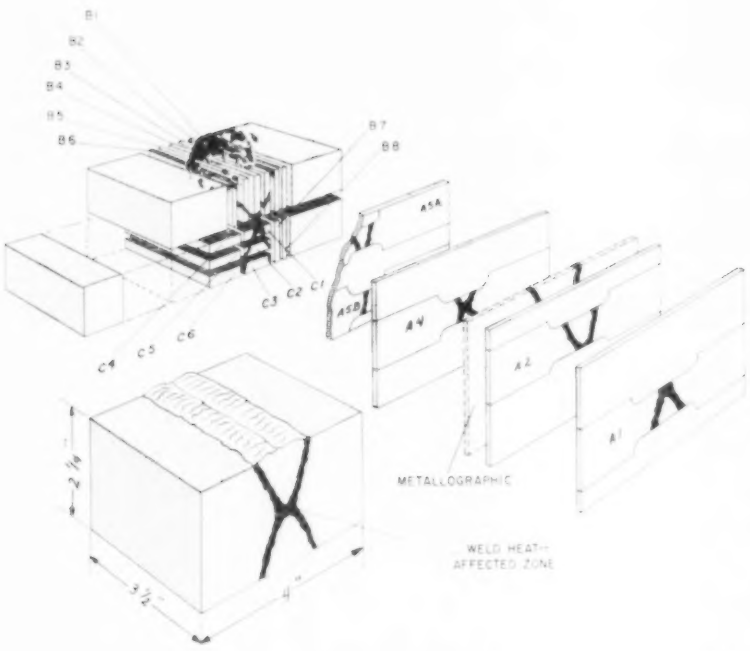


Fig. 1 Exploded view of $2^1/_4$-in. thick weldment in Zircaloy-2 showing location of test specimens

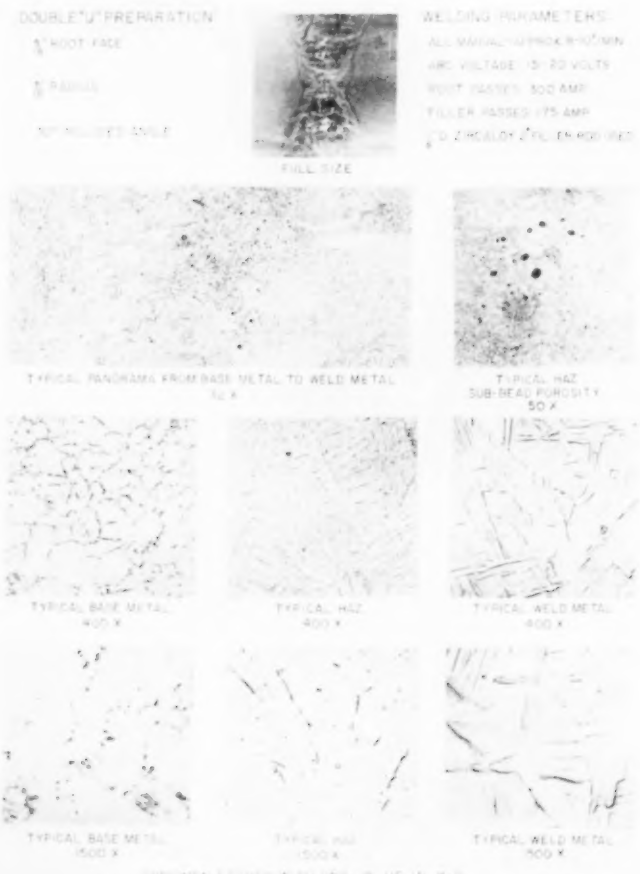


plate. It is further hoped that this paper may stimulate work along this line by those fortunate enough to have the time to pursue problems of primarily academic interest.

Test Results

32-Pass Zircaloy-2 Weldment

Preparation. The limited amount of material available for this phase of the work necessitated making a joint between two 2-x $2^1/_4$-x $3^1/_2$-in. blocks (Fig. 1). It may be inferred from calculations based on published thermal data[7] for $^1/_2$-in. titanium plate that blocks of this size, in relation to the known weld energy input, act as infinite heat sinks for single-pass weldments. By controlling interpass temperature, essentially single-pass conditions were achieved as is confirmed by the general pattern of the weld heat-affected zone shown in Fig. 2. A double "U" preparation was selected based on previous experience in welding thick Zircaloy sections. The details of the welding procedure followed are given in Appendix B.

Sufficient material was machined from one end of the weldment to avoid end effects; a hardness survey was taken, and the block was sectioned as illustrated in Fig. 1. The tensile specimens were machined as shown in the top sketch of Fig. 4, where the over-all and shoulder lengths are given as minima.

The corrosion samples (Fig. 7) of base metal, heat-affected zone, and weld metal could not be machined from the block of Fig. 1 for obvious reasons. In consideration of weld thermal data from $^1/_2$-in. thick titanium, a trough of 1-in. thick Zircaloy-2 from the 1-x $4^1/_2$-in. bar was designed, such that all the wrought material would transform to heat-affected zone after filling the trough with weld metal. The same welding conditions and filler wire used in making the 32-pass weldment were employed. Control specimens were machined from the 1-x $4^1/_2$-in. bar adjacent to the material used to make the trough.

Structures. The microstructures of typical regions of the weldment are shown in Fig. 2. For the sake of convenience, no attempt has been made to locate specific higher-magnification fields on the lower-magnification prints. All photomicrographs were made from the same specimen, shown as a full-size photomacrograph (originally $2^1/_2$-in. high), and all may be considered typical of the indicated portions of the weldment.

The microstructure of the weld metal

←

Fig. 2 Microstructure of a 32-pass weldment in a $2^1/_4$-in. Zircaloy-2 plate. (Reduced by $^1/_3$ upon reproduction). (HAZ = Heat-affected zone)

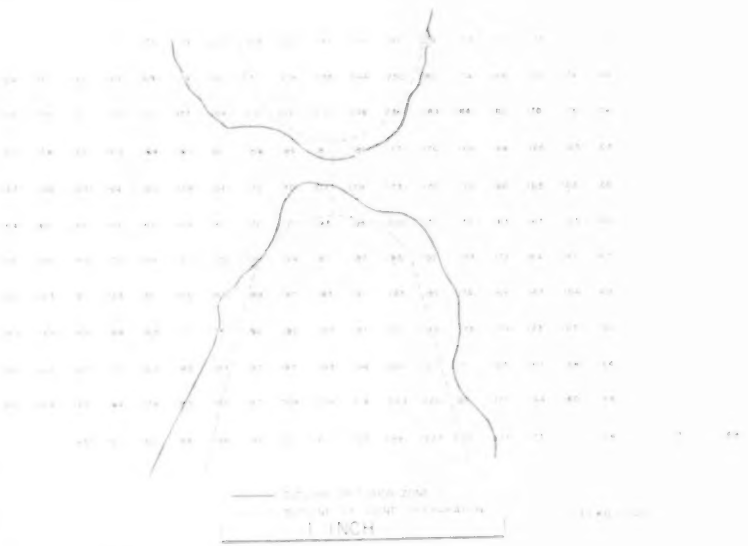


Fig. 3 Diamond pyramid hardness readings

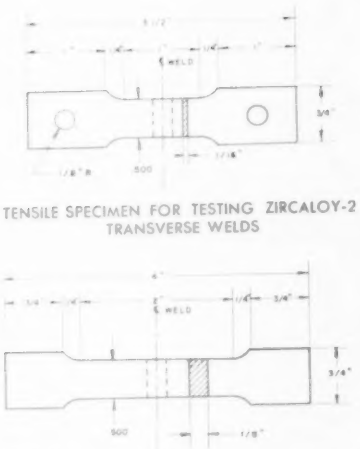

WELD
TENSILE SPECIMEN FOR TESTING ZIRCALOY-2 TRANSVERSE WELDS
WELD
TENSILE SPECIMEN FOR TESTING ZIRCALOY-3 TRANSVERSE WELDS

Fig. 4 Tensile specimens

is composed of Widmanstätten alpha grains oriented with respect to the prior beta grains in which they formed. These large families of alpha grains are definitely related to mechanical properties through differences in slip mechanism between families and the effect of prior beta-grain boundaries. It is interesting to note the development of pronounced shear planes at about 45° to the axis of loading in tensile sample A5B (Fig. 5), where the preferred orientation has caused slip in two preferred directions. These phenomena have been noted in zirconium.[8]

The specks along the alpha-grain boundaries in the heat-affected zone, particularly evident in the "×400" photomicrograph of Fig. 2, are believed to be etch pits. The lines present in the × 1500 photomicrograph of the heat-affected zone but absent in the × 400 photomicrograph are believed to be partially resolved hydride platelets.

The typical base-metal photomicrographs show precipitation of intermediate phases along the comparatively equiaxed alpha-grain boundaries.

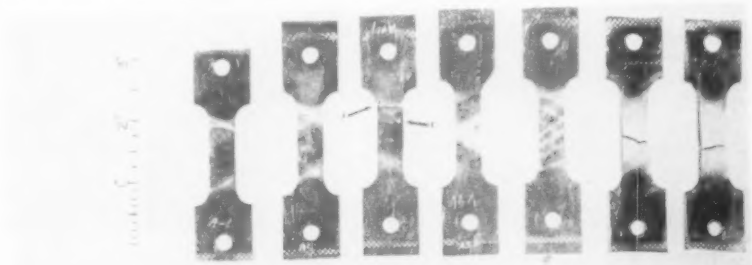
The sub-bead porosity, clearly illustrated in the × 50 photomicrograph, is exaggerated by the chemical polishing of the specimen.

Test Results. Tensile tests were performed on an Instron testing machine equipped with an X-Y recorder. A photograph of the tensile specimens with data is shown in Fig. 5. The sub-bead porosity is considered to have very little, if any, practical significance. That the tensile specimens broke preferentially in the heat-affected zone is due to the higher strength of the neighboring weld metal rather than to a loss of strength in the heat-affected zone. This difference in properties is illustrated by the relative hardness (Fig. 3) and difference in grain size (Fig. 2) where both high hardness numbers and large grains (in zirconium) are associated with increased strength. This is verified by the data of Fig. 5 where the strength of the weld metal is higher than that of the base metal.

Bend specimens $\frac{1}{8}$-in. thick and $\frac{3}{4}$-in. wide were tested at room temperature in a jig with a $\frac{3}{4}$-in. diam, hardened and ground, loading nose and hardened and ground roller supports $\frac{1}{2}$ in. diam on $1\frac{1}{4}$-in. centers. Testing continued until the load began to drop off. It may be noted in Fig. 6 that extensions were welded to the bend specimens to facilitate testing, but the joints so formed were spaced further apart than the supports. Thus the test results were not affected by the modification. In all cases, the bend specimens had the side that was closest to the weld axial centerline in tension during the test.

The bend specimens of Fig. 6 do not indicate significant differences between weld metal, heat-affected zone and base metal. Generally speaking, the maximum load for the control samples was less than that for the weld metal and the heat-affected zone. That none of the large-grained samples failed catastrophically is probably due to the difficulty of propagating a crack through unfavorably oriented, large prior beta grains.

The corrosion-tested coupons are shown in Fig. 7. All samples were statically corrosion tested after degreasing and pickling. The tests were standard, that is, degassed special purity water of 6 to 8 PH with a conductivity of 0 to 2 micromhos/cm, was used at 680° F as water at the saturation pressure and at 750° F as steam under 1500 psi pressure. It was noted that a considerable number of stringers was



SPECIMEN NO.	A-1	A2	A4	A6A	A5B	B1	B2
SPECIMEN TYPE	WELD	WELD	WELD	WELD	WELD	CONTROL	CONTROL
ULTIMATE STRENGTH	72.2	77.8	74.0	76.0	76.0	71.0	71.8
0.2% YIELD STRENGTH	—	62.0	62.0	60.4	58.4	50.8	50.0
% ELONGATION IN 1"	10	15	5	19	19	26	25
% REDUCTION OF AREA	21	30	18	24	20	30	27

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Fig. 5 Tensile data from 32-pass weldment in $2\frac{1}{4}$-in. plate

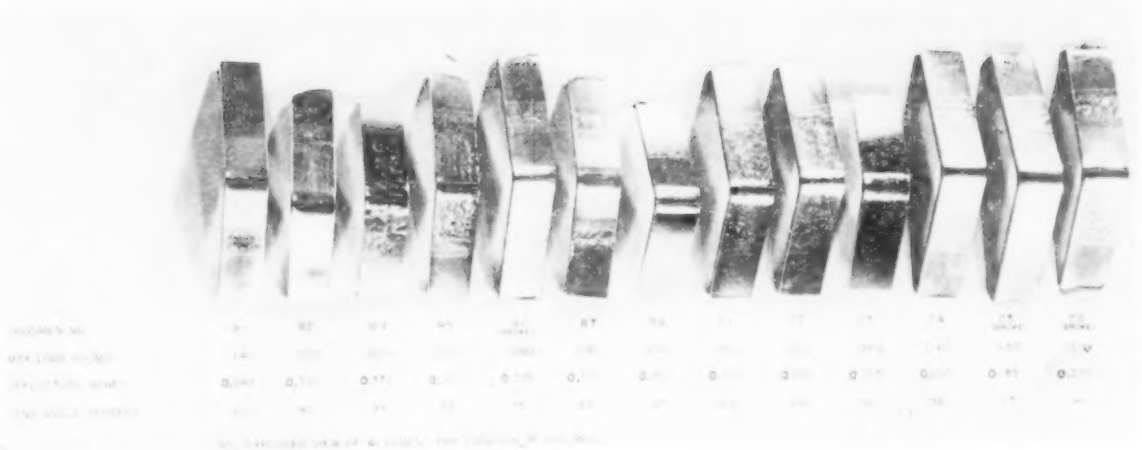

Fig. 6 Bend test data from 32-pass weldment 2 1/4-in. plate

evident in the base metal after preparation for corrosion testing, and the as-tested samples show stringer corrosion on the base metal and attenuation of stringer corrosion on the heat-affected zone. The effect of grain orientation can be seen on the surface film of the weld-metal specimens.

The corrosion data are presented graphically in Fig. 8 with "standard" curves for both environments. These exhibit two important trends. The curves for the base metal and heat-affected zone are quite similar, both being higher than the standard curve. The second trend is the consistently-lower corrosion rate of the weld metal. Well-annealed Zircaloy-2 will exhibit better corrosion resistance and will not show the surface effects noted on this material but will develop a uniform shiny black film.

Welded Zircaloy-2 Plates

Preparation. The material for this phase of the study was taken from the hot-rolled strips of Zircaloy-2 (Appendix A) which were butt welded as described in Appendix B. Tensile specimens were machined from both welded and unwelded material to a common thickness of 1/16 in. according to the upper drawing of Fig. 4.

Structures. Typical structures of the 1/4-in. plate in the as-welded condition are shown in Fig. 9. The photomacrograph at the top of the figure clearly illustrates the distinctiveness of the weld bead, heat-affected zone and base metal. The first and last-named structures are shown in greater detail in photomicrographs B and C. The structure of the heat-affected zone varies from that shown in photomicrograph D, where the metal was heated to just above the transformation temperature, to that portion of the heat-affected zone nearest the weld bead (photomicrograph E) where the metal was heated to a temperature slightly below the melting point. In the transition zone E, the structure suffers more irregularity than in the central portion of the heat-affected zone by virtue of the higher temperature to which it has been exposed.

Sub-bead porosity is in evidence as fine horizontal lines in the photomacrograph where the condition has been exaggerated by chemical polishing. Note that the shrinkage stresses imposed on the unpenetrated portion of the joint have caused some deformation (upsetting), evidenced by curvature of the porosity which is normally parallel to the rolling direction. Such high contractual stresses imposed on a welded butt joint cause solid-state bonding, resulting in a tensile strength equivalent to that of a fully penetrated joint.

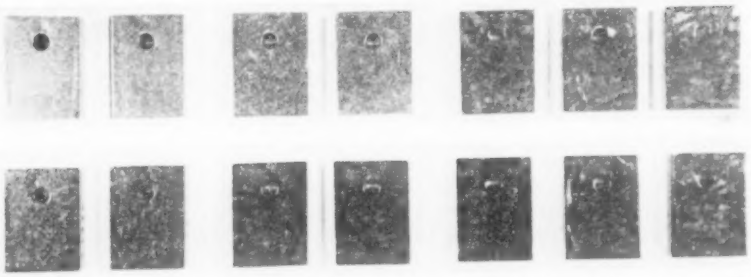

Fig. 7 Corrosion coupons machined from a multipass weldment (approximately 2/3 size)

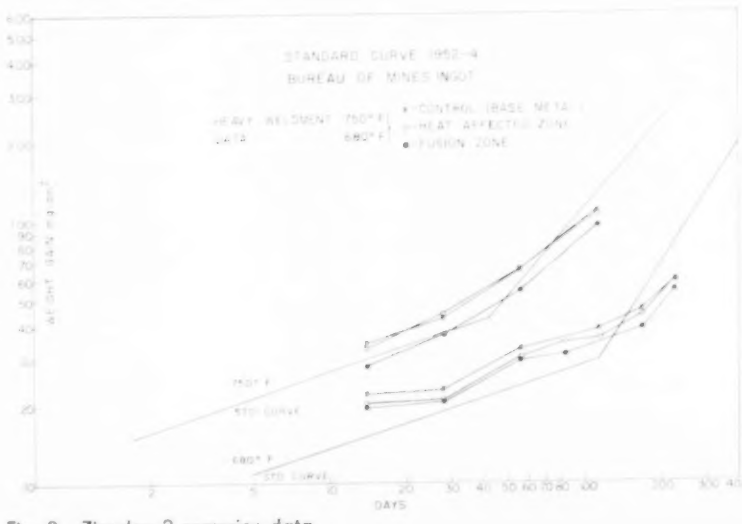

Fig. 8 Zircaloy-2 corrosion data

Heat Treatment. The tensile specimens were heat treated in sealed Vycor bulbs, as detailed in Appendix C. A complete heat-treating schedule was not set up at the outset inasmuch as it was expected that early trends would indicate subsequent treatments. It is emphasized that the heat treatments were selected to produce the most deleterious properties of the welded structures. Since it was known that heating into the beta region (roughly 1000° C) causes a loss of ductility through the excessive growth of beta grains, both welded and as-rolled specimens were treated in Vycor bulbs at 1000° C for 1 hr and furnace cooled.

With the results of these initial tests at hand, it was decided to investigate two parameters; namely, treatment temperature and cooling rate. Hence, the remaining specimens were divided between two treatments: half were heated to 900° C for 1 hr and furnace cooled, and the other half were heated to 1000° C for 1 hr and air cooled without breaking the Vycor bulbs.

Test Results. The tensile data from these tests are shown in Fig. 11, where each bar of the nomograph represents an average of at least 2 (or 3) tests. In all cases, the yield strength has been omitted since it is believed that some, if not all, of the specimens may have slipped in the grips of the tensile machine, thus allowing localized yielding at the alignment holes prior to general yielding in the reduced section of the specimens.

Slow cooling subsequent to high-temperature treatments in both plate thicknesses lowered ductility rather than strength by considerable amounts. The change in structure effected by welding increased the specimen strength over that of the hot-rolled material with a concurrent loss of ductility; then subsequent deleterious thermal treatments lowered the strength and ductility of the specimens. It should be noted that the specimen strength has been raised and lowered by special combinations of welding and heat treatment, but in no case has the ductility been improved beyond, or even restored to, that observed in specimens of the hot-rolled material.

Welded Zircaloy-3 Plates

Preparation. The $\frac{1}{4}$-in. Zircaloy-3 sheet (Appendix A) was prepared by passing an arc across the as-rolled sheet to produce a simulated joint and eliminate the variable of joint fitup. The welding technique is described in Appendix B. Each fusion pass yielded three tensile specimens oriented parallel to the rolling direction with the simulated weld traversing each specimen as shown in the second drawing of Fig. 4. Alignment pins were not used with these specimens, thus avoiding localized yielding near the holes (note specimens B-1 and B-2, Fig. 5). A specimen could slip without producing noticeable deformation around the hole, but the yield strength as determined from a load-elongation record would be of doubtful value. Without alignment pins, slippage was easily detected on the chart record and the specimen could be regripped without discrediting the test.

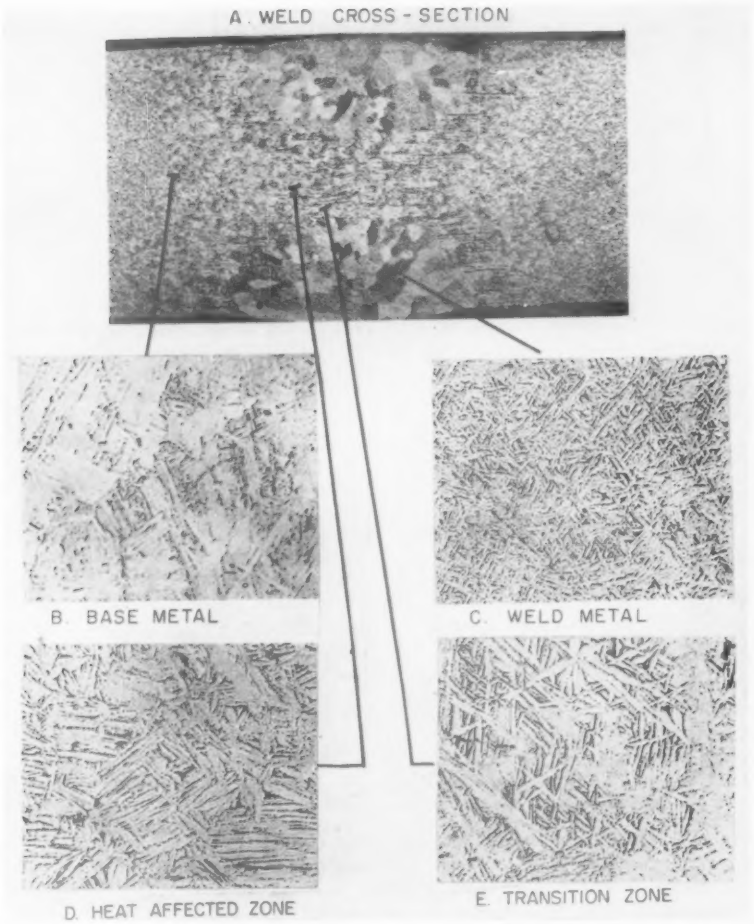

Fig. 9 Zircaloy-2, $\frac{1}{4}$-in. plate, as-welded, showing various structures. A: X $3\frac{1}{2}$; B, C, D and E: X 400. (Reduced by $\frac{1}{3}$ upon reproduction)

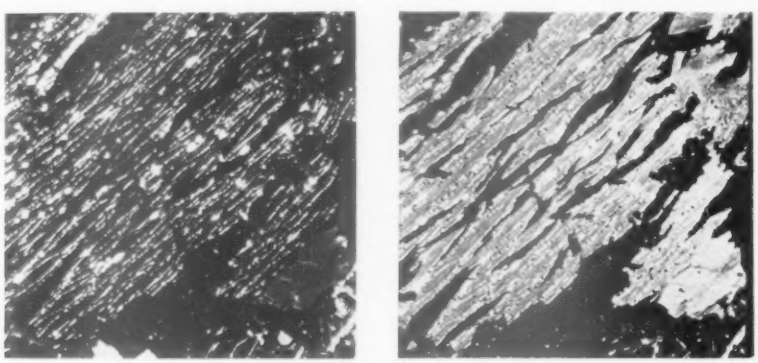

Fig. 10 Heat-affected zone of weld shown in Fig. 9, polarized light, two orientations of specimen selected to emphasize evidence of a precipitate. X 500. (Reduced by $\frac{1}{3}$ upon reproduction)

Heat Treatment. The tensile specimens were heat treated in sealed Vycor bulbs as detailed in Appendix C. The following treatment schedule was adopted as being one which would

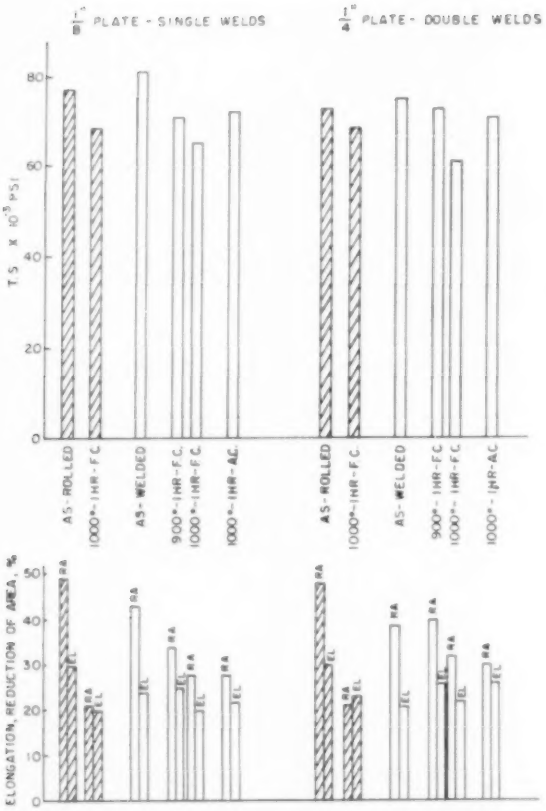

Fig. 11 Tensile properties of rolled Zircaloy-2 plates with transverse fusion welds. Treatment temperatures in degrees centigrade. (A.C. = air cooled in Vycor bulbs. F.C. = furnace cooled)

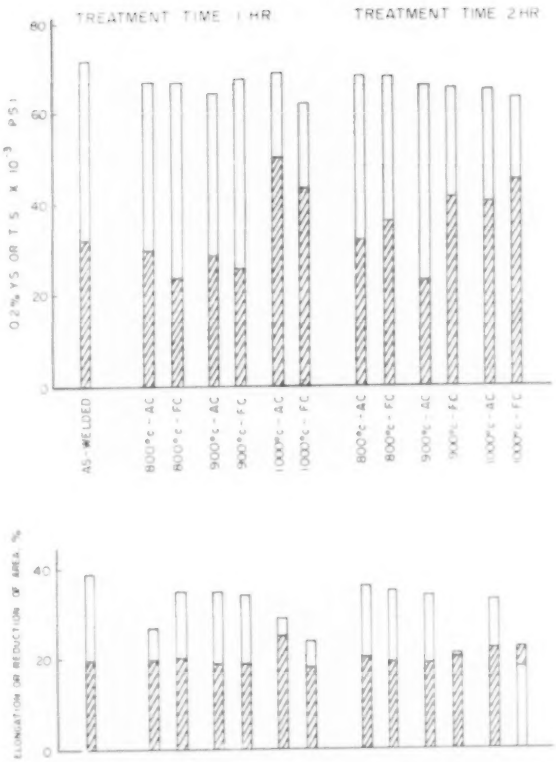

Fig. 12 Tensile data for Zircaloy-3 transverse fusion welds. Yield strength and elongation are represented by shaded bars

yield significant information in the light of the Zircaloy-2 data: (*a*) as-welded; (*b*) 800° C, 1 and 2 hr, furnace cool and air cool; (*c*) 900° C, 1 and 2 hr, furnace cool and air cool; and (*d*) 1000° C, 1 and 2 hr, furnace cool and air cool.

Four tensile specimens were given each treatment. The specimens were so selected that only one from each individual weld was given a single treatment, and no more than two specimens per treatment came from the same transverse position (right, center or left). It is believed that this sampling procedure normalized, as much as possible, the statistically distributed variables being measured.

Test Results. The tensile data are presented as a nomograph in Fig. 12, where each value is an average of four tests. From unpublished work, it has been found that the material from the top fourth of the particular ingot (FZ-466) used in this study had average tensile properties as given in Table 1. These data were not included on the nomograph because, although taken from a nearby portion of the same ingot, the fabrication history was different. It can be seen that furnace cooling from a treatment temperature lowers the strength slightly and the ductility considerably.

Welding appears to increase the ultimate strength and reduction of area while decreasing the yield strength and elongation. (Beta-quenching changes the properties in the same fashion, but not necessarily to the same degree.) The effect of treating the welded tensile specimens by slow cooling is progressively to lower the ultimate strength with increasing treatment temperature while the elongation is essentially unchanged. Much more noticeable are the changes in yield strength and reduction of area which progressively increase and decrease, respectively, to a considerable extent with increasing treatment temperatures. A rank-correlation coefficient calculation shows that the hypothesis (prediction) that the reduction of area will decrease when the yield strength increases has better than 95 chances out of 100 of being correct. Finally, there appears to be very little difference between air cooling in Vycor bulbs and furnace cooling, or between treatment times of 1 hr and 2 hr.

Discussion

Zircaloy welding is accompanied by at least three distinct metallurgical phenomena. These are: (1) the effect

Table 1—Mechanical Properties of the Zircaloy-3 Used in this Investigation in Conditions Other than Welded

	Averages of 8 Tests			
Condition	*0.2% Yield strength, psi*	*Tensile strength, psi*	*Total elong., %**	*Red. of area, %*
Hot rolled	45,500	63,600	25	33
Beta-quenched†	59,200	80,400	6	19
1000° C-1 hr-F.C.	39,300	62,900	9	19

* One in. gage length.
† Heated into the low beta region and quenched.

of beta-grain size, (2) the appearance of a precipitate and (3) sub-bead porosity. Any welding study results will be influenced by the existence of such phenomena and a discussion of them here is of importance.

Some of the material in a Zircaloy weld heat-affected zone is heated briefly into the beta region. This material (composing most of the heat-affected zone) and all of the weld metal will then cool rapidly enough to be considered beta-quenched. Because of the established $\beta \rightarrow \alpha$ transformation orientation relation,[9] each prior beta grain will become a family of similarly-oriented alpha grains. It has also been established that beta-quenching increases the strength of Zircaloy with an attendant loss of ductility as measured by tensile elongation.[10] It has been suggested that this may be due to a concentration of impurity atoms at the prior beta grain boundaries and or a difference in slip mechanism between neighboring families of alpha grains. Although the mechanism remains unresolved, the fact that the changes occur accounts for the high strength of the weld metal and the adjacent portions of the heat-affected zone which were "betatized."

Other investigators have reported a correlation between the appearance of a "precipitate" and the embrittlement of Zircaloy subjected to deleterious heat treatments. The authors, too, have observed similar "precipitates" as is illustrated in Fig. 10. But this is not a typical area in that it required considerable searching to discover such a quantity of particles. It seems quite certain that the precipitate particles are actually etch pits as they are best seen on chemically polished, rather than mechanically polished, specimens. But the authors have not been able to retain real particles in any metallographic specimens, nor have they found any correlation between a precipitate and brittleness. Although it is not their intention to argue from the lack of evidence, it must be noted that the etching characteristics may arise from factors other than the precipitation of second phases.

Porosity of the heat-affected zone in Zircaloy welds is a common occurrence, as illustrated in Figs. 2 and 9. This must be the result of argon gas which, at elevated temperatures, will agglomerate. It should be noted that sub-bead porosity always occurs as long, thin holes parallel to the rolling direction in plate material in a similar manner to stringers. In both cases, then, there should be little, if any, effect on the longitudinal properties with the occurrence of such highly oriented microstructures.

Of specific interest in this welding study are the property changes involved in welding and heat treatment. Niemann and Sopher[5] stated or implied that serious metallurgical problems exist in the multipass welding of Zircaloy-2; however, the authors feel that undue emphasis was placed on the embrittlement problem. This criticism is based on the belief that weld thermal cycles cannot be synthesized by furnace treatments.[6] To conclude that such treatments produce metallurgical effects similar to those found in welding is misleading. Although special treatments will embrittle Zircaloy, this is of no engineering importance since such treatments are not realized in the fabrication of nuclear components. It is apparent that the change in mechanical properties imposed by welding is less than that imposed on unwelded material by a beta anneal and slow cooling. Superimposed on the welding effects are those caused by the change in geometry of tensile specimens when a weld is incorporated in the reduced section. Because the weld metal is harder than the base metal, it can be predicted that it will also be stronger and less ductile. Thus, the situation in a tensile specimen which incorporates a weld is one wherein two materials with greatly different properties are connected in series. The weld metal acts as a restraint, thus lowering the measured tensile ductility just as effectively as if the gage length of the specimen had been severely reduced.[11] On the other hand, the effect on the strength measurements should be very little, if any, where the analogy is the weakest-link-in-a-chain concept.

Because individual welds responded to the deleterious heat treatments to a lesser degree than the base material, it can be concluded that even if multipass welding imposed a similar treatment, the resulting property changes would not be cause for alarm. Since known weld thermal-cycle data for other materials lead one to predict that these treatments are not reproduced in multipass welding, where the time at temperature is shorter and the cooling rate higher, it is certain that multipass welding will not be detrimental to the mechanical properties of fabricated Zircaloy components. That this is, in fact, the case is proved by the tensile specimens machined from the 2¼-in., 32-pass weldment. Again, it must be noted that the observed mechanical properties of these specimens have been affected by both the welding and the relation of specimen inhomogeneity to specimen geometry. It is well known that stress concentrations exist at the shoulders of tensile specimens, and in the case of the specimens machined from the 32-pass weldment, this is just where the transition between weld metal and heat-affected zone occurred. Nothing can be concluded from this study concerning the possibility of an interaction between these factors to cause failures where they did, but this first attempt at analyzing such a multipass weldment will be followed by others which will account for such possibilities in advance.

It has been noted that zirconium or Zircaloy weld metal exhibits corrosion rates as good as, or better than, the base metal, provided adequate atmospheric control is used during welding.[12] The corrosion data for the heat-affected zone, however, indicate that some factor is acting to produce an apparently abnormal weight gain. The material which exhibited excessive porosity (i.e., the heat-affected zone and stringered plate) had an initially high weight gain in corrosion testing, followed by an abnormally low weight gain in the post-transition period. The data for the base metal and heat-affected zone metal tested in 750° F steam (Fig. 8) illustrate this point. Initially, both types of material had weight gains in excess of the standard curve and the weld metal, but at longer times the corrosion rates of the porous materials were lower than that of the weld metal. This change in rate after long exposure is even more apparent in the curves for the 680° F water test. This behavior is explained by the fact that stringers corrode more rapidly than the matrix and the thicker corrosion product resulting from the excessive rate may break off during the later stages of corrosion, resulting in some weight loss. It may be supposed that sub-bead porosity exhibits the same effect. Although the weld metal was sound, orientation effects may operate locally to increase the corrosion rate.

Care must be taken in comparing weld metal to that of an ingot since the only thing the two structures have in common is solidification from the liquid state. The better corrosion resistance of weld metal is a function of less grain boundary segregation, having been more rapidly cooled from the liquid state. Thus, the excellent corrosion behavior of weld metal cannot be extrapolated to predict the behavior of ingot metal.

Summary and Conclusions

1. A 32-pass weldment in 2¼-in. Zircaloy-2 plate was made and tested. The structural differences across the zones of the weldment were noted and correlated with mechanical properties. In general, it can be stated that such multipass welds in Zircaloy-2 are excellent from an engineering viewpoint.

2. Zircaloy-2 and Zircaloy-3 plates were subjected to welding and the results of an initial heat-treatment survey indicate that mechanical properties may be impaired by certain deleterious post-welding heat treatments.

3. Several factors of obvious importance to the understanding of Zircaloy weldments are discussed, namely:

(*a*) the effect of prior beta grains, (*b*) the presence of a "precipitate" in the microstructure and (*c*) the effect of sub-bead porosity.

4. The mechanical test results indicate that the property changes realized in multipass welding are minor in comparison with those incurred in welds which were subsequently subjected to known deleterious treatments.

5. Corrosion studies confirmed the existing knowledge of the excellent corrosion behavior of weld metal and the undesirable effect of either stringers or sub-bead porosity.

Acknowledgments

The authors wish to thank Dr. F. Forscher, Dr. J. Hino, Mr. A. Klein and Dr. D. E. Thomas for many helpful suggestions and continued encouragement. Credit is also due to Messers D. L. Cain, R. Holstine, J. G. Landkrohn and K. Marsh for performing much of the experimental work and to the many service organizations associated with the Westinghouse Atomic Power Division for their support.

The authors are grateful to the U. S. Atomic Energy Commission and Westinghouse Electric Corp. for permission to publish this work.

Appendix A

Material

The Zircaloy-2 used in Phases 1 and 2 of this study was taken from a 1000-lb production ingot which was double-arc melted under a static argon atmosphere from a sponge blend. Ten Brinell tests (3000 kg) produced readings which ranged from 158 to 172, averaging 165. That part of the ingot used for this investigation was essentially free of porosity and other defects as determined by ultrasonic and visual inspection. The ingot was cogged and forged to a 4-x 4-in. billet at the vendor's plant. Subsequently, the part which was used in this investigation was forged and hot-roll flattened to a $2^1/_2$-x $5^1/_2$-x 30-in. bar. No microstructural evidence of directionality could be detected in the bar in a plane parallel to the rolling plane. Approximately 1 ft of the $2^1/_2$-x $5^1/_2$-in. bar was subsequently rolled to a 1-x $4^3/_8$-in. bar for corrosion-test specimens.

A 1-ft length of the 1-x $4^3/_8$-in. bar was then hot-rolled at 1550° F to $^1/_4$-in. thickness by taking 20 to 25% reductions in thickness in each pass. The bar was preheated for 30 min prior to rolling and reheated for 10 min between each pass. One-third of the length was sheared off and rolled down to $^1/_8$-in. thickness by the same rolling schedule.

The chemistry of the Zircaloy-2 ingot is given in Table 2.

The Zircaloy-3 used in Phase 3 of this study was taken from a 500-lb ingot which was triple-arc melted under a static argon atmosphere from a sponge blend. Ten Brinell tests (3000 kg) produced readings which ranged from 156 to 163, averaging 159. That part of the ingot used for this investigation was essentially free of porosity and other defects as determined by ultrasonic and visual inspection. The ingot was cogged and forged to a 4- x 4-in. billet at the vendor's plant. Approximately 16 lb of the 4 x 4 billet was cut from the top quarter and hot-rolled, using the same rolling schedule as previously described, to $2^1/_2$-in. x $^1/_8$-in. x length. The chemistry of the Zircaloy-3 ingot[7] is given in Table 3. It may be seen from this analysis that several elements do not fall within the allowable range, but a check analysis resolved the discrepancies as follows:

Sn (average of 12 analyses)..... 0.23%, range: 0.21–0.25%

Table 2—Chemical Analysis of the Zircaloy-2 Used in this Investigation

Alloying Elements Expressed as Weight Percentages

Alloy	*Number of samples*	*Range of 100% of samples*	*Range of 90% of samples*	*Average of 100% of samples*
Sn	19	1.39–1.47	1.39–1.47	1.43
Fe	19	0.116–0.128	0.119–0.128	0.124
Cr	19	0.100–0.110	0.100–0.109	0.106
Ni	19	0.047–0.050	0.047–0.050	0.049

Major Impurities

Nitrogen—Average 0.0043%, Range 0.0040 to 0.0048%, Maximum 0.0048%
Carbon—Top 0.021%, Bottom 0.031%

Minor Impurities from Chip Analysis

Expressed as parts per million. Precision of ±30% of amount present.

	Bottom	*Center*	*Top*
Al	39	32	32
Co		<10	
Cu		16	
Hf		<50	
Mg		2	
Mn		21	
Mo		<10	
Pb	82	90	76
Si		15	
Ti		<20	
V		<20	
W		<50	
B		<0.1	
Cd		<0.1	

Table 3—Chemical Analysis of the Zircaloy-3 Used in This Investigation

Alloy Elements Expressed as Weight Percentages

Alloy	*Number of samples*	*Range of 100% of samples*	*Range of 90% of samples*	*Average of 100% of samples*
Sn	5	0.32–0.33	0.32–0.33	0.325
Fe	5	0.26–0.27	0.26–0.27	0.265

Major Impurities

Nitrogen—Average 0.0037%, Range 0.0031 to 0.0040%, Maximum 0.0040%
Carbon—Top 0.0040%, Bottom 0.0030%

Minor Impurities from Chip Analysis

Expressed as parts per million. Precision of ±30% of amount present.

	Bottom	*Top*
Al	61	54
Co	<10	<10
Cu	76, 90	43
Hf	<100	<100
Mg	<10	<10
Mn	33	30
Mo	<20	<20
Pb	<20	<20
Si	140	127
Ti	<25	<25
V	<25	<25
W	<25	68
B	<0.2	<0.2
Cd	<0.2	<0.2

Si (average of 6 analyses) ..... 85 ppm, range: 79–91 ppm
Cu (average of 6 analyses) ..... 56 ppm, range: 46–59 ppm

Thus, the material used was within specification with the exception of an excess of 6 ppm of copper which should not be deleterious.

Appendix B

32-Pass Zircaloy-2 Weldment

The preparation of the weldment employed a $\frac{1}{16}$-in. root face, no root spacing, and "U"s" of $\frac{5}{16}$-in. radii with 30-deg included angles. Welding was done manually using the following parameters:

Travel speed	8–10 in./min
Arc voltage	15–20 v
Root passes	300 amp
Filler passes	175 amp
Interpass temperature	250° F

Welding parameters were checked by a stop watch and an Esterline-Angus recording-type ammeter and voltmeter. All welding was done using direct current of straight polarity (electrode negative) from a 400 amp, dry-disc rectifier. A $\frac{1}{8}$-in. diam 2% thoriated-tungsten electrode was used in a chamber which was evacuated to less than 0.03 microns of Hg, held at this pressure for a period of 8 hr, then subsequently back-filled with high-purity helium. One-eighth in. filler wire, swaged from material of the same ingot, was manually fed into the arc and the only pass sequence employed was that of welding alternate sides consecutively.

Welded Zircaloy-2 Plates

The hot-rolled strips of Zircaloy-2 were grit blasted and pickled to reduce surface contamination, then machine slit transverse to the rolling direction to produce ten $2\frac{1}{2}$-x $4\frac{1}{2}$-in. pieces and one 5-x $4\frac{1}{2}$-in. piece from both gage plates. The smaller coupons were butt welded (square-butt preparation with no gap) to produce four sets of joints maintaining the original rolling direction. Welding was done in a controlled-atmosphere welding box as previously described, using a $\frac{1}{16}$-in. diam tungsten electrode with a 0.4 flat tipped conical point having a 30° included angle. The arc length was automatically controlled to produce an arc voltage of 16.5 v and the work was passed under the arc mechanically at 10 ipm. A single pass using 70-amp current was employed for the $\frac{1}{8}$-in. plate welds and two passes, each using 100-amp current, were employed for the $\frac{1}{4}$-in. plate welds, these passes being made along opposite edges of the joint interface. The coupons were tungsten-arc spot tacked prior to welding and clamped to minimize distortion during welding.

Welded Zircaloy-3 Plates

The hot-rolled strip of Zircaloy-3 was sheared into four equal lengths for ease in handling; then, after cleaning and pickling, transverse arc welds were made in a welding box, as described above. However, in this case, the arc was passed across the as-rolled sheet to produce a simulated joint and eliminate the variable of joint fitup. A total of 36 simulated welds were made using an arc travel speed of 10 ipm with a current of 65 amp to obtain 100% penetration.

Appendix C

Heat Treatment

Preparation of the tensile specimens and bulbs prior to treatment involved a thorough detergent wash followed by water, then alcohol rinses. To getter any gases, cleaned and pickled crystal-bar chips were also put in the bulbs. The bulbs were dried, evacuated for 16 hr to 10^{-5} mm Hg, filled with purified argon to a pressure of 230 mm Hg and sealed. Heating was done in a muffle furnace with triple controlling to ±2° C. Air-cooled specimens were removed from the furnace and cooled in still air without breaking the bulbs.

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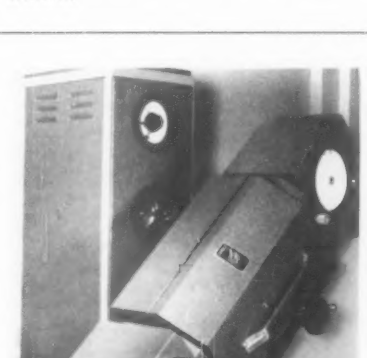
RESEARCH NEWS

Spectrography

Direct reading spectrographic analyzers manufactured in the USA use the so-called "integration" method. Intercontinental Electronics Corp., Mineola, N. Y. is reportedly introducing in this country, the Automatic Spectro-Lecteur, the first direct reader which permits measurement of instantaneous values, and, therefore, direct and instantaneous reading of analysis results without resorting to integration. In direct reading spectrochemical analysis, the measurement is achieved by means of photomultipliers. However, the photomultipliers are used differently in the "integration" method and in the "Spectro-Lecteur" system.



The first method, which is the one used by the heretofore available direct reading instruments, consists in charging condensers through as many photomultipliers as there are lines in the spectrum to be recorded. The time during which the condensers are charged truly represents an integration, quite similar to the integration of the photographic plate.

According to the manufacturer, the "Automatic Spectro-Lecteur" only includes two photomultipliers; one views the line of the basic metal in the alloy, whereas the other one travels automatically along the focal plane of the spectrum, stopping at selected lines for a determined length of time according to a pre-arranged program. Thus there is a continuous measurement of instantaneous values of the intensity ratio between the recorded lines and the line of the basic metal.

Norelco Adds to Personnel

Norelco service facilities have been further strengthened through the addition of five new employees, according to an announcement by the Instruments Div., Philips Electronics, Inc., 750 S.

(*Continued on page 20-s*)

IMPROVED NOTCH TOUGHNESS OF EXPERIMENTAL SEMIKILLED STEELS OVER ONE INCH IN THICKNESS

Test results indicate that a semikilled steel containing about 0.16% C and 1.20% Mn may have sufficient notch toughness to be considered as an emergency substitute, or possibly as an alternate, for ABS Class C killed steel in thicknesses over 1 in. to 1¾ in. inclusive

BY R. W. VANDERBECK

ABSTRACT. A substitute for ABS Class C killed ship-plate steel (over 1 in. thick) is desirable because it is likely that, during an emergency, hot-topping capacity would not be available for the production of ship plate. To provide a semikilled steel of suitable toughness, a cooperative investigation was undertaken to produce and test two 25-ton basic open-hearth semikilled heats containing lower carbon and higher manganese than present ship-plate steels. Tests on the plate product indicate that this steel is tougher than presently used semikilled grades and should be sufficiently tough to consider as an emergency substitute, or possibly as an alternate, for ABS Class C steel in thicknesses over 1 in. to 1¾ in. inclusive. To meet the tensile properties specified by the American Bureau of Shipping for hull steel, it is tentatively proposed that the composition range for this steel be about 0.20% carbon maximum and 1.00 to 1.35% manganese. Exact limits must, of course, be based upon extensive production and testing of commercial-size heats. The proposed steel should have about the same sensitivity to underbead cracking as ABS Class C steel. It is recommended that a number of full-size heats be made and tested so that average properties and the likely range of properties may be better determined and optimum deoxidation practices established.

Introduction

An interpretive report has been published on the "Metallurgical and Economic Aspects of Ship Steels and Their Relation to Ship Failures," by W. J. Harris, Jr., and Clyde Williams of Battelle Memorial Institute, prepared for the Ship Structure Committee.[1] One of the recommendations of this study is that, as an emergency substitute for ABS Class C* killed steel, consideration be given to the use of a semikilled steel containing lower carbon and higher manganese than ABS Class B semikilled steel. It is desirable to obtain a substitute for the killed Class C steel because during an emergency it is likely that hot-topping capacity would not be available for the production of ship plate. Harris and Williams conclude from their analysis of the notch-toughness behavior of plates that failed in ship service that, for satisfactory service performance, the alternate steel should have an average 15 ft-lb Charpy V-notch transition temperature not exceeding about 10° F for thicknesses over 1 in. (equivalent approximately to 0° F for 1-in. thick plate).

The Advisory Committee on Project SR-141 was formed to develop a program for the procurement and testing of semikilled steel plate of the proposed

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* All references to American Bureau of Shipping specifications for steel in this report relate to Section 39 of the 1955 edition of the Rules for Building and Classing Steel Vessels.

Table 1—Melting and Processing Data

	Heat 1 (2G2850)	*Heat 2* (2G2883)
Additions		
Bath	400 lb medium C FeMn 145 lb 25% FeSi	350 lb medium C FeMn 150 lb SiMn
Ladle	375 lb medium C FeMn 11 lb graphite	388 lb medium C FeMn 18 lb Recarb-X
Mold	1 lb Al	2½ lb Al
Total weight produced	47,000 lb	52,500 lb
Tap temperature	2995° F (optical)	2935° F (optical)
Pour temperature	2875° F (optical)	2840° F (optical)
Ingot size	30- × 64- × 89½-in.	30- × 64- × 89½-in.
Slab size	8- × 62- × 65-in. long	8- × 62- × 65-in. long
Slab finishing temperature	2035° F (optical)	1980° F (optical)
Slab reheating temperature	2420° F	2420° F

Heat	*Slab*	*Plate size, in.*	*Plate finishing temp., ° F*
Heat 1	B	¾ × 72 × 220 (B-1) ¾ × 72 × 220 (B-2)	1840
	C	1¾ × 72 × 275	1940
	D	1¾ × 72 × 180	2000
Heat 2	A	1¾ × 72 × 180	1940
	B	¾ × 72 × 220 (B-1) ¾ × 72 × 220 (B-2)	1800
	C	1¾ × 72 × 260	1905
	D	1¾ × 72 × 180	1980

lower-carbon, higher-manganese variety, for few data were available to indicate the combination of properties that would be obtained in such a steel. Based upon the analysis of Harris and Williams, plus suggestions made by the Advisory Committee, it was proposed to make and test two 25-ton heats of semi-killed steel containing about 0.15% C and somewhat over 1.00% Mn. The objective was to obtain a 15 ft-lb Charpy V-notch transition temperature of 0° F or lower in 1-in. plate thickness since it was believed that this would provide satisfactory performance in service. It was also desired to maintain the tensile properties presently speci-

Fig. 1 Distribution of samples from each plate

Table 2—Tests Conducted by the Investigators

	Investigating Laboratory					
Type test	*ABS*	*Esso*	*NCRE*	*NRL*	*NYNSY*	*USS*
Chemical analysis	*	*		*		*
Tensile properties	*					*
Ferrite grain size		*				*
McQuaid-Ehn grain size	*					
Grain coarsening	*					
Keyhole Charpy	*			*		*
V-notch Charpy	*	*		*		*
Crack-starter drop-weight				*		
Crack-starter explosion				*		
SOD		*				
Robertson			*			
Navy tear					*	
Underbead cracking						*

Table 3—Chemical Composition

		Ladle Analysis, %												
		Heat 1 (Heat 2G2850)	0.16 C	1.30 Mn	0.010 P	0.021 S	0.08 Si							
		Check Analyses on Plates from Heat 1, %												
Slab	*Plate thickness, in.*	*Laboratory*	*C*	*Mn*	*P*	*S*	*Si*	*Cu*	*Ni*	*Cr*	*Mo*	*Total Al*	*Acid-sol Al*	*N*
B	¾	USS (C)*	0.18	1.26			0.044							
		USS (Q)†	0.17	1.26			0.040							
		ABS‡	0.18	1.31	0.018	0.035	0.040							
		Esso§	0.18	1.27	0.018	0.021	0.039							
		NRL	0.21	1.31	0.013	0.017	0.050							
C	1¼	USS (C)	0.16	1.26			0.040							
		USS (Q)	0.16	1.24			0.040					0.008	0.006	
		ABS	0.17	1.30	0.016	0.032	0.040							
		Esso	0.18	1.35	0.014	0.021	0.033							
		NRL	0.16	1.26	0.012	0.018	0.050							
D	1¾	USS (C)	0.14	1.22			0.043							
		USS (Q)	0.14	1.22	0.010	0.019	0.043	0.06	0.13	0.08	0.01	0.008	0.006	0.002
		ABS	0.16	1.26	0.014	0.027	0.040							
		Esso	0.18	1.27	0.013	0.019	0.033							
		NRL	0.16	1.26	0.010	0.018	0.050							
		Heat 2 (Heat 2G2883)	0.15 C	1.04 Mn	0.013 P	0.022 S	0.021 Si							
		Check Analyses on Plates from Heat 2, %												
A	1¼	USS (C)*	0.15	1.13			0.015							
		USS (Q)†	0.15	1.15	0.011	0.024	0.014	0.04	0.02	0.04	None	0.006	0.003	0.003
		ABS‡	0.15	1.08	0.011	0.028	0.030							
		Esso§	0.18	1.08	0.013	0.025								
		NRL	0.17	1.06	0.010	0.024	0.020							
B	¾	USS (C)	0.16	1.04			0.017							
		USS (Q)	0.15	1.02			0.016							
		ABS	0.18	1.04	0.010	0.038	0.020							
		Esso	0.14	1.09	0.012	0.027	0.014							
		NRL	0.16	1.01	0.009	0.028	0.020							
C	1¼	USS (C)	0.15	1.02			0.016							
		USS (Q)	0.15	1.02			0.018					0.006	0.004	
		ABS	0.16	1.03	0.009	0.033	0.010							
		Esso	0.16	1.06	0.012	0.023	0.014							
		NRL	0.17	1.06	0.006	0.024	0.020							
D	1¾	USS (C)	0.11	0.99			0.020							
		USS (Q)	0.12	0.99	0.011	0.019	0.017	0.03	0.02	0.04	None	0.008	0.004	0.004
		ABS	0.14	0.96	0.011	0.022	0.020							
		Esso	0.13	1.02	0.015	0.021	0.019							
		NRL	0.14	0.97	0.005	0.022	0.020							

* C = centerline position in plate.
† Q = quarter-width position in plate.
‡ Analyses conducted by R. W. Hunt Co.
§ Analyses conducted by New York Testing Laboratories.

fied by ABS. Since the principal use of the alternate grade would be in thicknesses over 1 in. up to possibly 1¾ in. (like ABS Class C), the heats were to be rolled to several different thicknesses that would encompass this range. The thicknesses selected were ¾ in., 1¼ in. and 1½ in. The ¾-in. thickness would be useful for making comparisons with ¾-in. ABS Class B steel, on which considerable data were available. A detailed testing program was outlined, and the heats were made and were tested by various investigators as described below.

Melting and Processing of Heats

The two heats were made at the Gary Steel Works of the United States Steel Corporation in their 25-ton foundry, basic open-hearth furnace to the following composition:

Carbon, %	0.15 aim
Manganese, %	1.05 aim
Phosphorus, %	0.04 max
Sulphur, %	0.05 max
Silicon, %	0.10 max (semikilled)

Table 1 shows pertinent melting and processing data on these heats. One 30- x 64- x 89½-in. ingot was cast from each heat, and four slabs, numbered A, B, C and D, were produced from each ingot. Slab A was the top slab of the ingot. In the first heat, the top cut was lost because of pipe. As a result, slab A was not obtained. The second heat was deoxidized to a lesser extent (lower silicon), and all four slabs were obtained as planned. The slabs were rolled to plates of ¾-in., 1½-in. and 1½-in. thickness as noted in Table 1, and samples were then cut from each plate in the manner shown in Fig. 1 for distribution to the various investigating laboratories.

Tests Conducted

The various groups which conducted tests on these steels in this cooperative program were the American Bureau of Shipping, Esso Research and Engineering Co., Naval Construction Research Establishment (Scotland), Naval Research Laboratory, New York Naval Shipyard and United States Steel Corp. These names are henceforth abbreviated as shown in Fig. 1.

The tests that were conducted by these organizations are outlined in Table 2. A few of these tests require some further explanation. The crack-starter drop-weight test has been fully explained by Puzak, *et al.*[2, 3] This test is used to determine the nil-ductility transition temperature (NDT) below which fracture may be readily initiated but above which considerable forcing is required to initiate failure.

The crack-starter explosion test is used to determine the fracture-transition temperature. Fracture, once initiated, will propagate through elastically-loaded

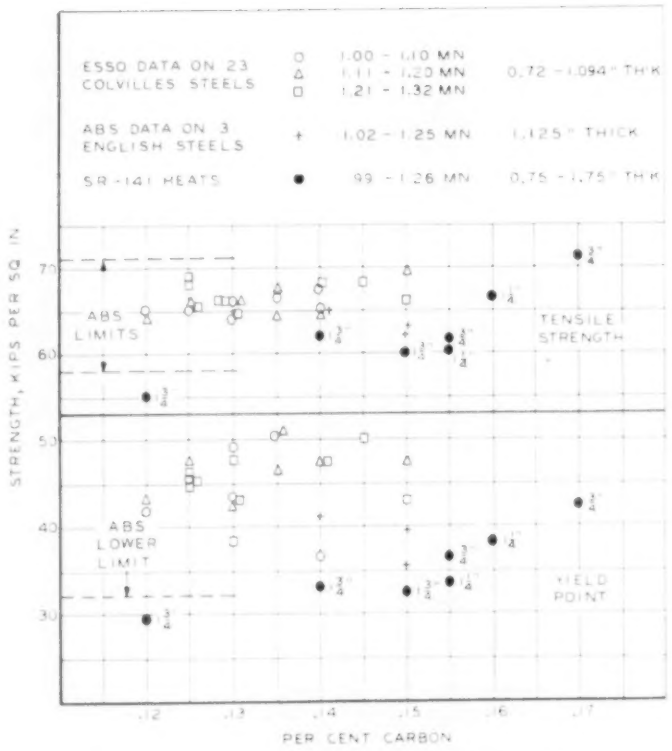

Fig. 2 Effect of carbon content on yield point and tensile strength

Table 4—Tensile Properties

Heat	Plate thickness, in.	Laboratory	Yield point, psi	Tensile strength, psi	% Elongation, in. 2 in.	% Elongation, in. 8 in.	% R.A.
Heat 1	¾	USS (C)*	42,300	71,360		30	
		USS (Q)†	42,500	71,060		30	
		ABS	41,800	69,300		30	
	1¼	USS (C)	39,240	66,430		31	
		USS (Q)	37,760	66,520		30	
		ABS	36,400	65,000		32	
	1½	USS (C)	33,030	62,150		35	
		USS (Q)	33,160	61,970		34	
		ABS	32,100	60,600		34	
		USS (C)‡	33,950	61,900	39		69.3
		USS (Q)‡	35,670	61,660	38		68.8
Heat 2	¾	USS (C)	35,020	61,580		33	
		USS (Q)	37,790	61,660		34	
		ABS	35,150	60,200		33	
	1¼	USS (C)	33,050	60,270		32	
		USS (Q)	33,650	60,200		37	
		ABS	31,300	57,500		35	
	1½ (Slab D)	USS (C)	29,350	55,140		38	
		USS (Q)	29,390	55,030		38	
		ABS	29,400	54,200		37	
		USS (C)‡	29,220	55,720	42		71.6
		USS (Q)‡	28,480	55,970	42		72.1
	1½ (Slab A)	USS (C)	32,230	60,050		37	
		USS (Q)	32,360	59,930		38	
		ABS	32,600	58,900		34	
		USS (C)‡	31,450	60,670	41		72.7
		USS (Q)‡	31,450	60,920	42		70.4

* C = centerline position in plate.
† Q = quarter-width position.
‡ 0.505-in. rd tensile tests.

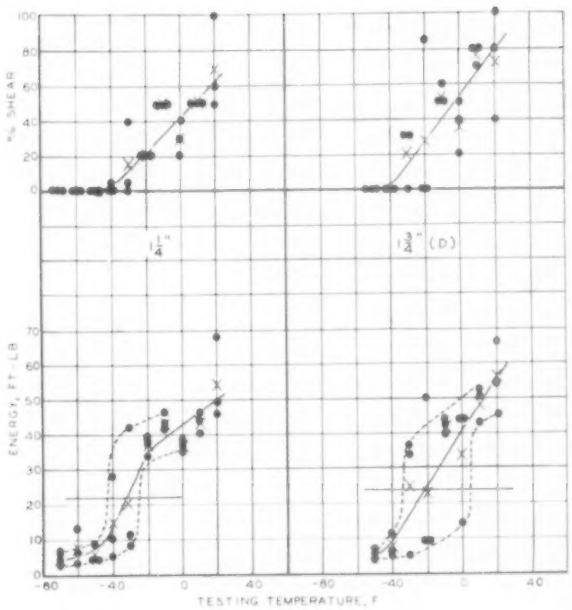

Fig. 3 USS keyhole-notch Charpy data, Heat 2

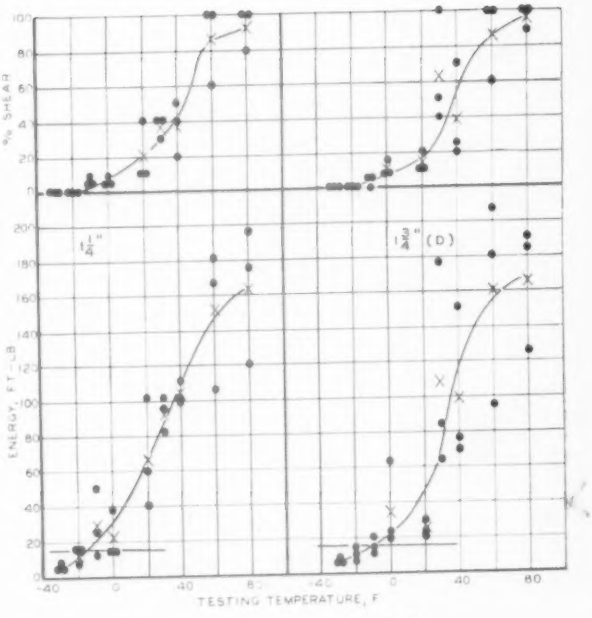

Fig. 4 USS V-notch Charpy data, Heat 2

regions below the fracture-transition temperature, while above this temperature it will not. Lately, this temperature has been referred to as the fracture transition for elastic loading (FTE). It corresponds quite well to the transition from shear to predominantly cleavage fracture in notched wide-plate specimens.

The SOD test[4] was conducted at a nominal tensile stress of 18,000 psi, using a 15° wedge and backing up the specimens with a 5000-lb weight. In this test fracture is initiated by an impact load acting upon the wedge, and the lowest temperature at which the crack will not propagate across the test specimen (at 18,000-psi tensile stress) is called the SOD transition temperature.

The Robertson test[5] is similar to the SOD test. The plate specimen is placed under load, and fracture is initiated by an impact load on the edge of the specimen. The Robertson test is usually run with a temperature gradient across the specimen, the crack being initiated at the cold temperature. The temperature of the plate where the crack stops is referred to as the Robertson-test transition temperature.

The Navy tear test has been fully described by Kahn.[6] This test is used to determine the fracture-transition temperature at which the mode of failure changes from shear to predominantly cleavage.

Van der Veen notch-toughness tests[7] are also to be conducted, and the results will be reported at a later date.

In general the notch-toughness tests may be divided into two groups, those that measure a ductility-transition temperature and those that measure a fracture-transition temperature. The ductility (or nil-ductility) transition indicates the temperature (in the particular test) above which fracture is not likely to *initiate* unless forced by appreciable deformation. The fracture-transition temperature indicates the temperature above which fracture is not likely to *propagate*. Between these two transitions, crack propagation can occur providing that fracture is initiated by forcing. Of the notch-toughness tests discussed, the crack-starter explosion, SOD, Robertson and Navy tear (and also van der Veen) measure fracture transitions. The crack-starter drop-weight measures a ductility transition. Evaluations of keyhole and V-notch Charpy data at about the 15 ft-lb level are also considered to provide measures of ductility-transition temperatures. More detailed explanations of these transition temperatures and of the test specimens used may be found in the listed references.

The underbead-cracking test[8] was used to determine the amount of cracking that could be expected adjacent to a weld bead when welding at various temperatures. This test is rather severe and usually provides much higher percentages of underbead cracking than are obtained in normal welding operations. The percentage of cracking is equal to the length of the cracked area,

Table 5—Grain-Size Evaluations

Heat	*Plate thickness, in.*	*ASTM ferrite grain size*		*McQuaid-Ehn grain size*
		USS	*Esso*	
Heat 1	¾	7–5	8	2–4
	1¼	6–7	9	2–4
	1¾	5–9	7	2–4
Heat 2	¾	7–5	8	1–4
	1¼	6–6	8	1–4
	1¾ (D)	5–8	8	1–4
	1¾ (A)	6–4	8	1–4

Austenitizing temperature, °F	*Grain-coarsening characteristics (of the 1¼-in. plate material only) ASTM grain size*	
	Heat 1	*Heat 2*
1550	7	7
1600	7	7
1650	6½	7
1700	7 (50%) and 3 (50%)	7
1750	2	7 (70%) and 3 to 5 (30%)
1800	2	1 to 2 (some 6)
1850	2	1 to 2

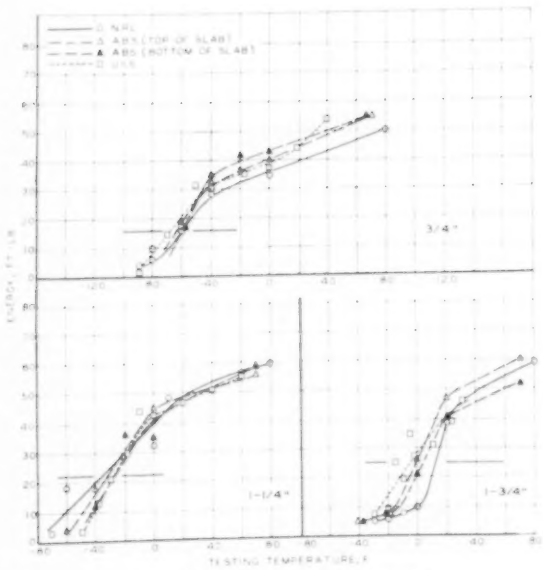

Fig. 5 Keyhole-notch Charpy data for Heat 1

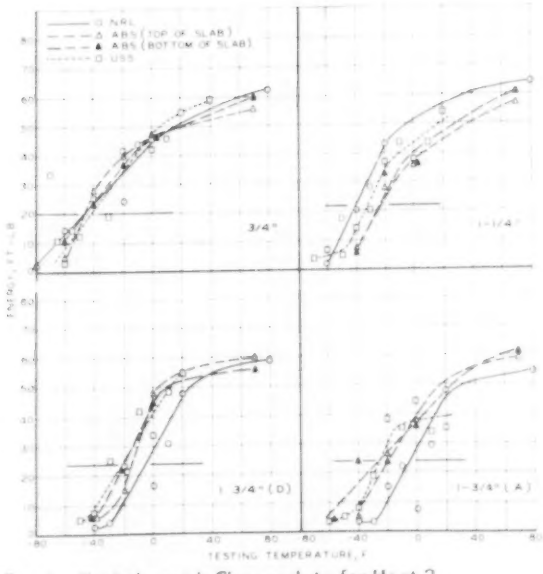

Fig. 6 Keyhole-notch Charpy data for Heat 2

times 100, divided by the total length of the weld bead.

Discussion of Test Results

Composition and Tensile Properties

Check analyses on the two heats (referred to as the SR-141 heats) are listed in Table 3, and tensile properties in Table 4. It will be seen from the results on slab D, Heat 2, that about 0.12 or 0.13% C and 1.00% Mn in 1½-in. thick plate are not sufficient to meet the tensile-strength range of 58,000 to 71,000 psi specified by ABS. Also, about 0.18% C and 1.25% Mn in ¾-in. plate (slab B, Heat 1) are slightly too high to meet this tensile-strength range. It appears that a carbon content of 0.15 or 0.16% and a manganese content of about 1.20% should be the aim to meet this range for plate thicknesses over 1 to 1½ in., inclusive. Heat 1 comes close to this composition. It might also be possible, if necessary, to adjust the aim slightly, depending upon the particular thicknesses required.

The minimum yield point specified by ABS is 32,000 psi, and those standard plate test specimens that show less than 58,000-psi tensile strength also have yield points under 32,000 psi.

Figure 2 shows the yield points and tensile strengths of some foreign steels, similar in composition to the SR-141 heats, plotted versus carbon content. Data for the SR-141 heats are also plotted, using the U. S. Steel data on strength and composition. The data on just the Colvilles plates indicate that variations in manganese in the range of 1.00 to 1.32% have a negligible effect on tensile strength. Probably more data would be needed to establish significant effects. The effect of carbon is also difficult to detect over the narrow range of 0.12 to 0.15% for the Colvilles plates, but there is an indication that tensile

Table 6—Charpy Impact Properties

Steel	Plate thickness, in.	Charpy V-notch 15 ft-lb transition temperature, °F				Keyhole Charpy ductility transition temperature, °F		
		ABS	NRL	USS	Esso	ABS	NRL	USS
Heat 1	¾	−25, −30	− 3	−32	−30	−64, −61	−60	−68
Heat 2	¾	− 2, − 8	−12	−16	0	−46, −46	−47	−42
ABS Class B	¾	23 avg (15 to 35) (8 hts)*				− 5 avg (−30 to 20) (8 hts)*		
		27 avg (15 to 35) (3 hts)†				−24 avg (−45 to 10) (9 hts)†		
	⅞	21 avg (4 to 41) (8 hts)*				− 6 avg (−15 to 5) (8 hts)*		
		26 avg (10 to 50) (4 hts)†				−10 avg (−46 to 21) (6 hts)†		
		25 avg (21 to 35) (4 hts)‡						
	1	45 avg (39 to 51) (5 hts)*				14 avg (5 to 20) (5 hts)*		
		23 avg (15 to 27) (3 hts)†				− 4 avg (−25 to 10) (3 hts)†		
		38 avg (30 to 60) (11 hts)‡				4 avg (−17 to 17) (4 hts)‡		
Heat 1	1¼	−10, −12	−21	− 6	<−20	−32, −28	−37	−28
	1¾	5, 5	0	− 6	< 0	− 2, 4	12	− 5
Heat 2	1¼	0, − 6	−11	−15	< 20	−22, −24	−40	−32
	1¾ (D)	0, 0	+ 2	−10	14	−15, −20	− 6	−22
	1¾ (A)	− 9, −12	− 5	−16	< 10	−20, −25	− 4	−25
ABS Class C	1	18 avg (8 to 35) (4 hts)*				−41 avg (−54 to −22) (4 hts)‡		
	1¼, 1½	−23 avg (−35 to −10) (14 hts)†				−68 avg (−92 to −34) (20 hts)†		
		− 8 avg (−16 to −2) (4 hts)*				−42 avg (−55 to −20) (4 hts)*		
	1¾, 1½	−11 avg (−40 to 17) (14 hts)†				−47 avg (−65 to −30) (15 hts)†		
		−10 avg (−23 to 3) (2 hts)*				−45 avg (−55 to −35) (2 hts)*		
	Over 1½, 2	−13 avg (−40 to 5) (10 hts)†				−46 avg (−70 to −20) (11 hts)†		

* Data from SR-125 (Reference 11). † Data provided by ABS. ‡ Data provided by NRL.

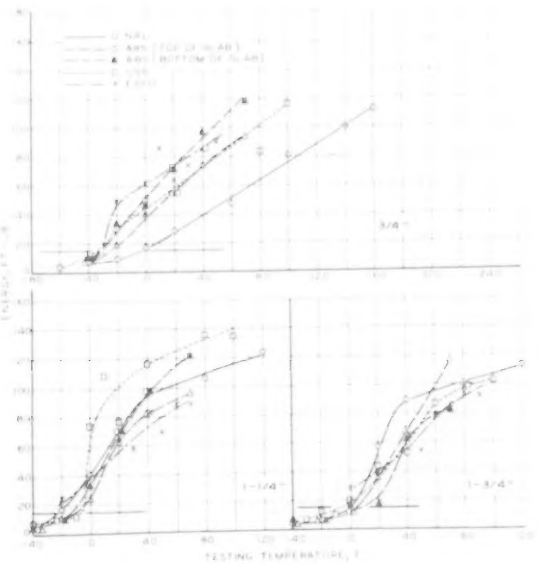

Fig. 7 V-notch Charpy data for Heat 1

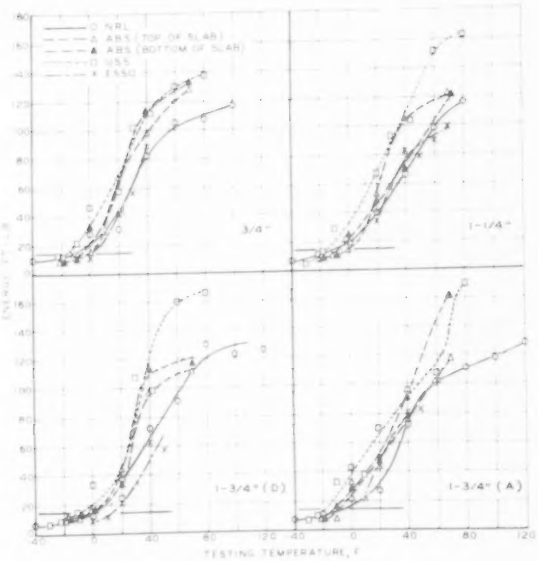

Fig. 8 V-notch Charpy data for Heat 2

strength increases with carbon content as expected. The three English steels and the SR-141 heats have lower tensile strength in general than the Colvilles plates for the same carbon content, but the former plates are thicker, except for the $\frac{3}{4}$-in. SR-141 plates. The yield points of the thicker plates are also lower. Different rolling procedures, as well as the differences in thickness, could account for some of the strength differences among these groups of steel.

Grain Size

Various grain-size evaluations are reported in Table 5. The U. S. Steel and Esso evaluations of ferrite grain size do not agree very closely, but different methods of evaluating grain size and, to some extent, different observers can bring about such discrepancies. The U. S. Steel evaluations are averages based upon 12 to 18 independent ratings (made by comparison with standard ASTM grain-size charts) and are therefore fairly precise. This is believed to be borne out by the regular manner in which grain size increases with plate thickness for each heat and by the correspondence of grain sizes for the same thicknesses in the two heats. The $1\frac{3}{4}$-in. plate from Slab A in Heat 2 is an exception to this consistent pattern in that its ferrite grain size is slightly finer than that for the other $1\frac{3}{4}$-in. plates, possibly because of its somewhat lower finishing temperature. These ferrite grain sizes seem normal for structural carbon steels in these thicknesses.

The McQuaid-Ehn grain size is that resulting from heating samples at 1700° F in a carburizing atmosphere. The grain size is coarse as would be expected for steel of this deoxidation practice.

The coarsening behavior of the heats is shown in the lower portion of Table 5. The samples were austenitized at various temperatures for 30 min and were then cooled at a rate suitable to provide good delineation of the grain boundaries. The grain-size ratings were based upon comparison with standard ASTM grain-size charts. These ratings are only rough estimates, especially where mixed grain sizes were obtained. A coarse-grained steel is said to coarsen gradually and consistently as the austenitizing temperature is increased, whereas a so-called fine-grained steel coarsens only slightly, if at all, up to a certain temperature and then coarsens abruptly. The tabulated data show that these heats apparently have coarsening characteristics similar to steels made to fine-grain deoxidation practice, despite the fact that only small amounts of aluminum were added to the mold and none to the ladle or bath (Table 1). For the approximately 20-ton ingots that were poured, the aluminum addition was 0.8 oz per ton for Heat 1, and 2 oz per ton for Heat 2. As noted in Table 3, the aluminum content in both heats was low. Rather abrupt coarsening of steels made to coarse-grain deoxidation practice may also be noted in data presented by Miller[3] so the behavior obtained here need not be considered exceptional.

It will be observed that coarse grains were obtained for Heat 2 in the McQuaid-Ehn test at 1700° F but not in the coarsening studies at 1700° F. This is explained by the fact that the specimen is at temperature for a longer time in the McQuaid-Ehn test.

The coarsening behavior does not influence the grain size of the hot-rolled product. It would only have an influence upon grain size if the steel were reheated.

With regard to deoxidation practice, it might be well to restate that Heat 1 was too heavily deoxidized, which resulted in pipe. The over-deoxidation was believed to be due mainly to the silicon content (0.04%), which is slightly high for semikilled steel of this composition. In Heat 2 with about 0.017% Si, the deoxidation was much more satisfactory, and there was no evidence of pipe in the rolled product. Suitable deoxidation practices may be better established if and when additional heats of this steel are produced, and it would be of interest to study further the grain-coarsening characteristics of some of these heats.

Charpy Impact Properties

All Charpy specimens were longitudinal with the notch normal to the plate surface.

Keyhole Charpy ductility-transition temperatures were obtained by drawing what was judged to be the best straight line through the averages of the energy values in the ductility-transition-temperature range (the range showing appreciable scatter of energy values from about 3 to about 35 ft-lb in these heats) and then selecting the transition temperature from this line at an energy level judged to be about midway between the high and the low energy values in this range. Examples of this technique are shown in Fig. 3, in which transition temperatures were selected at 22 ft-lb for the $1\frac{1}{4}$-in. plate and at

24 ft-lb for the 1¾-in. (D) plate. In this figure, each circle represents a single test, and the X's indicate the average of the energy values at each of the test temperatures. Curves have been drawn outlining the ductility-transition zone for these keyhole tests to show the extent of scatter.

Typical V-notch Charpy data are shown in Fig. 4. An average line was drawn through the averages (the X's), and the transition temperature was selected at 15 ft-lb for all of the plates.

The percentage of shear fracture (as opposed to cleavage) was observed for the broken U. S. Steel impact specimens, and typical plots of the data are also shown in Figs. 3 and 4. Fracture-transition temperatures were arbitrarily selected at 50% shear fracture.

The average curves for the impact data obtained by the various laboratories are presented in Figs. 5 through 8. The keyhole Charpy curves are in fair agreement, but the V-notch curves differ appreciably in some instances at the higher energy levels. The reasons for this are not known; the differences may be associated with machine differences and with real differences in material. It will be noted, however, that the curves for any one laboratory are not consistently high or low. At the 15 ft-lb level at which the V-notch transition temperatures were selected, the agreement is generally better than at higher energy levels. It will be seen from Figs. 5 and 6 that the keyhole Charpy transition temperatures were selected at the 16, 22 and 25 ft-lb levels for the ¾-, 1¼- and 1¾-in. plates of Heat 1 and at the 20, 22 and 24 ft-lb levels for the plates of the same thicknesses of Heat 2. These levels seemed most in keeping with the method of selection previously mentioned.

The Charpy transition-temperature evaluations of the SR-141 heats are listed in Table 6 along with similar evaluations of ABS Class B (0.60 to 0.90% Mn) and Class C steels. The keyhole Charpy portion of these data is plotted in Fig. 9. The two SR-141 heats have the same notch toughness in 1¼-in. plate thickness, and differ slightly in the ¾- and 1¾-in. thicknesses. Their transition temperatures are not so good as those of the ABS Class C steels, but even the heaviest plates have keyhole Charpy transition temperatures that are about as low as those of ¾-in. Class B plates.

The Charpy V-notch transition temperatures are plotted in Fig. 10. The 15 ft-lb temperatures of the SR-141 heats, even in 1¾-in. plate thickness, are considerably lower than those of the Class B heats and are almost as low as those of the Class C steels. An objective of this project was to obtain an average Charpy V-notch 15 ft-lb transition temperature of 0° F or lower for 1-in. plate thicknesses, since it was believed that such a transition temperature would provide sufficient toughness to eliminate practically brittle failures in ship service. This objective has been achieved in the SR-141 heats, for even the 1¾-in. plates have transition temperatures no higher than about 0° F. Moreover, the SR-141 heats are appreciably tougher in all thicknesses than the ABS Class B steels, and the latter steels have performed very well in ship service.

The V-notch Charpy results are believed to provide a better indication of service behavior than the keyhole Charpy results because of the correlation that has been developed between V-notch test data and ship performance,[10] but both the keyhole and V-notch tests do provide roughly the same relative ranking of these steels.

Figure 11 provides V-notch Charpy data on a number of semikilled, high-manganese steels of foreign manufacture for comparison with similar data on the SR-141 steels. The selected data on the SR-141 heats are average values (of the tests conducted by the various laboratories) for each of the seven plates tested. All of the steels are within the composition range of 0.12 to 0.17% C and 0.99 to 1.43% Mn, and all show rather similar notch-toughness behavior.

Table 7 shows an interesting evaluation of the differences between the 15 ft-lb V-notch and the keyhole Charpy ductility-transition temperatures of the SR-141 heats. For the evaluations by each laboratory, this difference decreases as plate thickness increases. This has not been previously realized, nor is it known if this is generally the case. For the 1¾-in. plate of Heat 1, the keyhole transition temperatures are about the same as the 15 ft-lb V-notch temperatures.

Since fracture appearance was recorded for the Charpy specimens tested by U. S. Steel, a list of the fracture-transition temperatures (at 50% shear) is presented in Table 8. For all plate thicknesses, the V-notch fracture transitions are approximately 45° F higher than the keyhole. The V-notch fracture transitions, like the V-notch 15 ft-lb transitions, are believed to provide better indications of critical temperatures in service than the keyhole Charpy evaluations. As discussed earlier, however, the 15 ft-lb and the fracture transitions evaluate different aspects of behavior.

Table 7—Difference Between 15 ft-lb V-Notch and Keyhole Charpy Ductility Transition Temperatures

Heat	Plate thickness, in.	15 ft-lb V-notch temperature minus keyhole Charpy ductility-transition temperature, °F— ABS	NRL	USS	Average
Heat 1	¾	39,31	57	36	41
	1¼	22,16	16	22	19
	1¾	7,1	−12	−1	−1
Heat 2	¾	44,38	35	26	36
	1¼	22,18	20	17	22
	1¾ (D)	15,20	8	12	14
	1¾ (A)	11,13	−1	9	8

Crack-Starter Drop-Weight Tests

The results of the crack-starter drop-weight tests are reported in Table 9, together with the energy absorbed in the Charpy V-notch test (NRL test data) at the crack-starter transition temperatures. The Charpy energy absorbed at the drop-weight transition is generally higher for the SR-141 heats than for ABS steels. Most of the SR-141

Table 8—Fracture-Transition Temperatures of Charpy Specimens Tested by USS

Heat	Plate thickness, in.	Fracture-transition temperature, °F at 50% shear V-notch	Keyhole	Difference*
Heat 1	¾	40	4	36
	1¼	30	−12	42
	1¾	44	−9	53
				44 avg
Heat 2	¾	42	−18	60
	1¼	44	8	36
	1¾ (D)	38	−4	42
	1¾ (A)	66	25	41
				45 avg

* Difference between V-notch and keyhole fracture-transition temperatures.

Table 9—Crack-Starter and Charpy V-Notch Test Data Obtained at NRL

Heat	Plate thickness, in.	Drop-Weight transition NDT, °F	Charpy V energy at NDT, ft-lb	Explosion crack-starter transition, FTE, °F	Charpy V energy at FTE ft-lb
Heat 1	3/4	−20	9	15	25
	1 1/4	0	10	35	91
	1 3/4	0	15	45	89
Heat 2	3/4	−10	16	25	53
	1 1/4	10	28	35	58
	1 3/4 (D)	10	22	35	60
	1 3/4 (A)	10	23	45	84

Note 1: Drop-weight transitions were determined on full-thickness specimens except for the 1¾-in. thick plate specimens which were machined to 1 in. thick. Explosion tests were on full-thickness specimens.

Note 2: The V-notch Charpy energy absorbed at the drop-weight NDT for as-rolled ABS steel is, according to NRL tests, as follows:

ABS steel	Plate thickness, in.	No. of heats	Charpy V energy at NDT, ft-lb — Average	Charpy V energy at NDT, ft-lb — Range	Charpy V Energy at FTE, ft-lb — Average	Charpy V Energy at FTE, ft-lb — Range
Class B	3/4	5	9	7 to 12		
	1	11	15	8 to 32		
Class C	1	4	13	10 to 17	45*	26 to 62*

* Based on 3 heats.

plates, however, are thicker than the ABS plates listed under Note 2, Table 9. The drop-weight transition temperatures are also listed in Table 10, where they may be compared with similar data on ABS steels and with V-notch Charpy 15 ft-lb transition temperatures. (These two transition temperatures are considered to be ductility-transition temperatures). The V-notch Charpy transitions are averages obtained from the data in Table 6.

The interpretation placed upon the drop-weight test by NRL is that brittle failure is a possibility at operating temperatures below the drop-weight transition temperature, but is not likely at temperatures above this transition unless crack initiation is forced. This interpretation is based upon the correlation with service behavior that was obtained with ship-plate steels of World War II manufacture, with some alloy pressure-vessel steels, and with some other steels in special applications. Based on this experience, NRL believes that the correlation would hold for a broad variety of steels.

Table 10 shows that eleven 1-in. ABS Class B plates had an average drop-weight transition of 35° F, and ABS Class B plates have so far performed well in service; in two instances, service failures have occurred in plates slightly outside the ABS Class B limits. The SR-141 plates over 1 in. thick, with drop-weight transitions of 0 to 10° F, are considerably better than the 1-in. Class B plates and similar in toughness to the ¾-in. Class B. According to the V-notch Charpy transitions, however, the heavy-gage SR-141 plates are considerably tougher than even the ¾- and ⅝-in. Class B plates. The two types of tests are therefore providing somewhat different evaluations of behavior. The V-notch Charpy transitions on the 1-in. ABS Class C steel are unusually high for this grade, so it would not be advisable to consider the average drop-weight transition of 8° F for these same heats as representative of the grade. (These high V-notch transitions for the 1-in. Class C plate show up clearly in Fig. 10; yet the keyhole Charpy transitions for these steels, Fig. 9, are not unusually high). Additional drop-weight tests on Class C steel are needed for a suitable comparison with the SR-141 heats.

Table 10—Various Transition-Temperature Evaluations

Steel	Plate thickness, in.	Ductility Transitions: Drop-weight transition, NDT, °F	Ductility Transitions: Average Charpy V 15 ft-lb temp., °F	Ductility Transitions: Crack-starter-explosion transition, FTE, °F	Fracture Transitions: SOD transition, °F	Fracture Transitions: Robertson test transition, °F	Fracture Transitions: Tear-test transition, °F	Charpy-V transition at 50% shear, °F
Heat 1	3/4	−20	−24	15	20		70	40
Heat 2	3/4	−10	−8	25	20	18	60	42
ABS Class B	3/4		24				60 avg* (8 hts) 64 avg† (40 to 90) 8 hts	
	5/8	4 avg (0 to 10) 5 hts	23				75 avg* (8 hts) 92 avg† (70 to 110) 9 hts 70 avg‡ (55 to 85)	
	1	35 avg (10 to 60) 11 hts	38		40 (1 ht)	(65)§	85 avg* (5 hts) 109 avg† (50 to 140) 21 hts	
ABS Class C	1	8 avg (0 to 10) 4 hts	18	57 avg (30 to 70) 3 hts	23 avg** (0 to 50) 6 hts			
	1 1/4–1 1/2		−16				80 avg* (6 hts)	
Heat 1	1 3/4	0	−12	35	50		70	30
	1 3/4	0	1	45	70		90	44
Heat 2	1 3/4	10	−8	35	50		90	44
	1 3/4 (D)	10	1	35	30		90	38
	1 3/4 (A)	10	−10	45	40		120	66

* Estimated from very limited tear test data in SR-125 (Reference 11).
† Kahn, *et al.* (Reference 6).
‡ Frazier, *et al.* (Reference 12).
§ A rough estimate based on limited data available (Reference 5).
** Reportedly all fine-grain-practice heats, but Al contents were low in some of the heats.

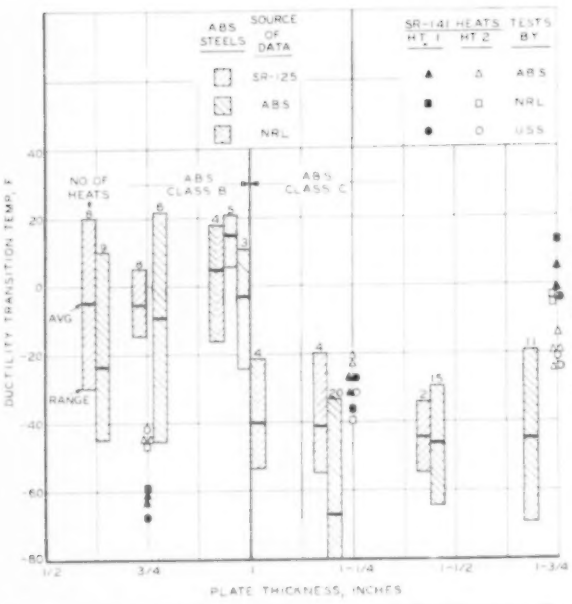

Fig. 9 Keyhole-Charpy ductility-transition temperatures of ABS and SR-141 Heats

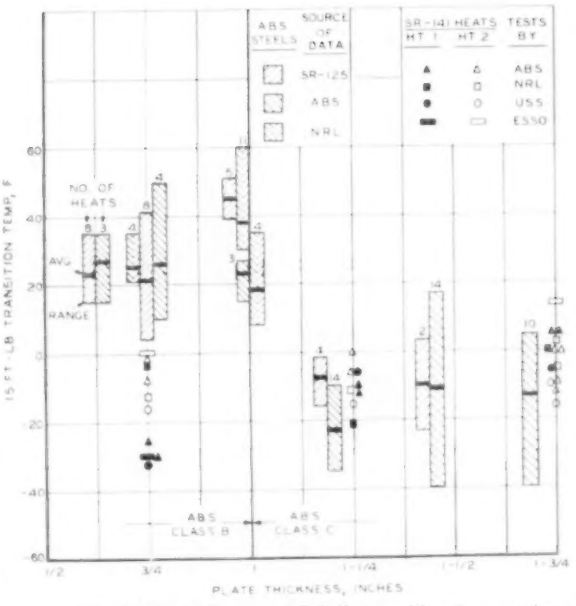

Fig. 10 V-Notch Charpy 15 ft-lb transition temperatures of ABS and SR-141 Heats

Fracture-Transition Evaluations

The fracture-transition temperatures as determined by the various test methods are also listed in Table 10. Evaluation of these results is hindered by the lack of comparable data for the ABS steels.

Crack-starter-explosion transition temperatures have been shown to agree quite well with fracture-transition temperatures obtained by centrally-notched wide-plate tests[3] which have been used extensively in testing certain pedigreed steels. The crack-starter-explosion transition temperatures for the SR-141 plates over 1-in. thick range from 35 to 45° F. This would seem to indicate that these plates would be highly likely to stop any cracks that might be initiated so long as the operating temperature is no lower than slightly above freezing. As a matter of interest, the Charpy V-notch energy absorbed at these transition temperatures is shown in Table 9.

The SOD transition temperatures agree fairly well with the crack-starter-explosion transitions except for the 1¼-in. plate of Heat 1. Also, the transition of the 1½-in. plate of Heat 2 seems out of line with the data on the 1¼-in. plates. Esso felt that the heavy thickness of these plate specimens may have been affecting the results appreciably and wished to conduct tests on samples planed down to 1 in. thick (all from one surface of the plate). Previous SOD tests by Esso have all been on plates no thicker than 1 in. Suitable supplementary samples were obtained (according to Fig. 1), and tests were run on the 1¼- and 1½-in. plates planed down to 1 in. The resulting SOD transitions were 20° F for the 1¼-in. plate of Heat 1 (as opposed to 70° F, not planed) and 30° F for the 1½-in. plate of Heat 2 (as opposed to 50° F). Esso cannot fully explain these results at this time other than to say that they may indicate the existence of a specimen-size effect.

The Esso tests on the ABS steels[4] were not conducted under the same conditions as those on the SR-141 heats. On the SR-141 material, the specimen was backed up with a 5000-lb weight, and a heavy charge was used to initiate fracture. On the other steels, no backing weight was used, and a reduced charge was employed. Esso reports that these two techniques have been shown to give very nearly the same SOD transition temperature.

The 23° F average SOD transition reported for 1-in. ABS Class C actually represents various grades of steel whose compositions fell within the ABS limits. However, the aluminum contents were quite low for some of these steels, which makes it questionable whether they were all made by fine-grain practice.

Robertson tests have been completed on just one plate to date, and detailed results are reported in Table 11. The transition temperature for the ¾-in. plate, Heat 2, is shown in Table 10. It agrees quite well with the crack-starter-explosion and SOD transitions.

Each tear-test transition temperature recorded in Table 10 represents the highest temperature at which 50% or more cleavage fracture was obtained in at least one out of four test specimens. This is the usual method of selection.

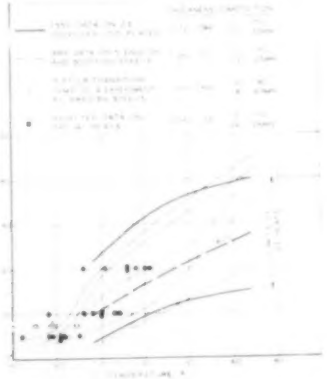

Fig. 11 Charpy V-notch impact behavior of high-manganese semikilled steels

All of the tear-test transitions are considerably higher than the fracture transitions obtained by the other test methods, and this has been the general experience with this test. The tear-test transitions on the SR-141 1¼-in. and 1½-in. plates are as high or higher than those obtained on the ABS steels.

Charpy V-notch fracture transitions are also listed, and in the heavier plate thicknesses they agree quite well with the crack-starter-explosion transition temperatures.

Underbead Cracking

The underbead-cracking test results are portrayed in Table 12 and are plotted versus carbon equivalent in Fig. 12, together with data on other types of steel, including ABS Classes A, B and C, HTS (Mn-V-Ti), X 52 line pipe (0.25% C, 1.00% Mn), and silicon-

killed, structural carbon steel. The figure shows that the amount of underbead cracking in all of these steels depends mainly upon the carbon equivalent, which is taken as being equal to the carbon content plus manganese over four plus silicon over four.

This underbead-cracking test is rather severe and often produces greater amounts of cracking than are obtained in actual welds. For example, 50% underbead cracking in this test on X 52 line pipe steel corresponds approximately to zero underbead cracking in field girth welds on line pipe.

It will be noted that greater amounts of underbead cracking are encountered at 0° F than at 60–70° F.

In general, these data indicate that SR-141 heats would have about the same tendency to underbead crack as ABS Class C steel.

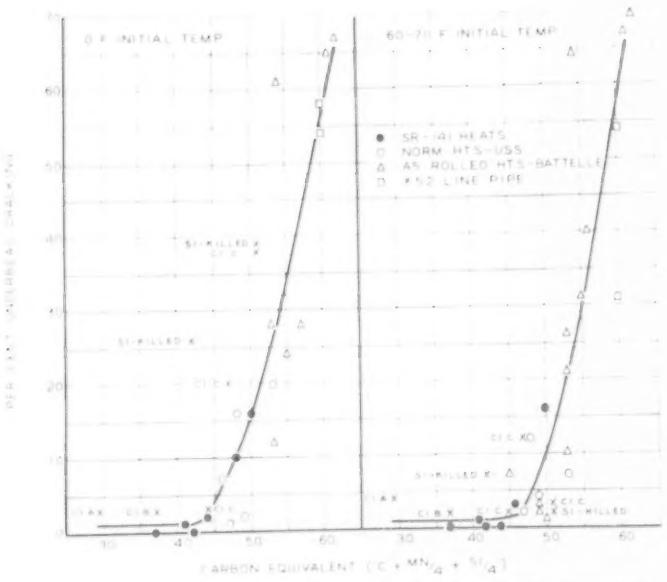

Fig. 12 Standard underbead cracking tests using E 6010 electrodes

Table 11—Robertson Test Data

Steel	*Stress, psi*	*Arrest temperature, ° F*	*Remarks*
Heat 2, ⅝-in. plate	22,400	14	
	17,920	18	
	13,440	18	
	11,200	−2	
	8,960	−23	
	7,840	−98	
	17,920* at 43° F		Crack ran through
	17,920* at 32 F		Crack arrested and repropagated

* These tests were conducted at the constant temperatures indicated except for a 2-in. long low-temperature zone under the notch. This zone was cooled so that fracture could be readily started.

Table 12—Standard Underbead-Cracking Tests

Heat	*Plate thickness, in.*	*Carbon equivalent**	*% Underbead cracking† at 0° F*	*70° F*	*212° F*
Heat 1	⅝	0.50	16	16	13
	1¼	0.48	10	7	1
	1¾	0.46	7	3	1
Heat 2	⅝	0.42	0	0	0
	1¼	0.41	1	1	0
	1¾ (D)	0.37	0	0	0
	1¾ (A)	0.44	2	0	1

* C + Mn/4 + Si/4 (based on USS check analyses).

† Using an E6010 electrode. When an E7016 low-hydrogen electrode was used, the underbead cracking at an initial temperature of 70° F was 0 to 2% for all plates.

NOTE: For ABS Class C, the average C equivalent is about 0.43; the maximum possible would be 0.55. For a 0.20 C max, 1.00–1.35 Mn semikilled steel, the average C equivalent (0.16 C, 1.20 Mn) is about 0.46; the maximum possible would be 0.54.

Conclusions

The objective of obtaining an average V-notch Charpy 15 ft-lb transition temperature of 0° F or lower in 1-in. thick semikilled plate was achieved in two heats containing about 0.15% C and 1.05–1.25% Mn. Even the 1¾-in. plates had transition temperatures no higher than about 0° F. According to V-notch Charpy tests, these heats were considerably more notch tough than ABS Class B steel and almost as good as ABS Class C. The crack-starter drop-weight tests also indicated good notch toughness but not as good as indicated by the Charpy V-notch tests. These tests imply that fracture would not start in these SR-141 heats, unless forced, at temperatures above approximately 0° F. The crack-starter-explosion tests indicate that the SR-141 steels would be highly likely to stop any cracks that might be started so long as service temperatures were no lower than about 40° F. These behavior characteristics compare favorably with those of ABS Class B steel and seem by some of the tests to be nearly as good as those of ABS Class C killed steel, but additional data are needed to make a suitable comparison in the latter case.

The test results are believed to indicate that a semikilled steel containing about 0.16 C and 1.20% Mn should have sufficient notch toughness to be considered as an emergency substitute, or possibly as an alternate, for ABS Class C killed steel in thicknesses over 1 in. to 1¾ in. inclusive.

To meet the tensile properties specified by the American Bureau of Shipping for hull steel, it is tentatively proposed that the composition range for this steel should be about 0.20% C maximum and 1.00 to 1.35% Mn. Exact limits must of course be based upon extensive production and testing of commercial-size heats.

Underbead-cracking tests indicate that the proposed steel should have about the same sensitivity to underbead cracking as ABS Class C steel.

Future Work

Only two 25-ton heats of the proposed steel have been tested to date. It has been the Project Advisory Committee's intention to consider making and testing full-size heats of this steel if the results obtained on these two heats were promising. Since promising results have been obtained, it is believed that

making selected tests on plates from a number of full-size heats is an appropriate step in order to establish better the average properties and the likely range of properties that might be expected. Also, additional mill experience is needed to establish optimum deoxidation practices for this steel.

Acknowledgments

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American Bureau of Shipping—D. P. Brown, G. W. Place; Esso Research and Engineering Company—F. J. Feely, Jr.; Naval Construction Research Establishment—T. S. Robertson; Naval Research Laboratory—W. S. Pellini, P. P. Puzak; New York Naval Shipyard—N. A. Kahn; United States Steel Corp.—M. W. Lightner; and Gary Steel Works—H. B. Wishart.

The members of Project SR-141 Advisory Committee, who planned and guided this study, are: M. W. Lightner, Chairman; W. J. Harris, Jr.; W. S. Pellini; T. S. Washburn; and T. T. Watson.

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RESEARCH NEWS

(*Continued from page 9-8*)

Fulton Ave., Mount Vernon, N. Y.

Thomas Murphy, Clay Littleton, George Walsh, Ronald Robbins and James Malloy are the individuals who recently joined the company. Murphy, Littleton and Walsh are currently being trained as field service engineers. These three men will be assigned to field offices in the near future.

Mr. Robbins has been appointed administrative assistant to Thomas Turnbull, service manager. Mr. Malloy assists Henry Court, sales administration manager, with orders and quotations.

Fred Dyroff has been transferred to the service department where he now serves as service foreman in charge of factory repairs. He also handles application studies on industrial X-ray equipment together with X-ray diffraction field service in the New York area.

X-ray

A new 12-page Norelco booklet, giving engineering data on X-ray instruments for element analysis and structure determinations, is available from the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Text covers basic diffraction equipment including cameras, the X-ray diffractometer and the X-ray spectrograph. A special section is devoted to the electronic circuit panel which is employed with diffractometer and spectrograph installations.

An entire page is allotted to the Norelco Autrometer, automatic X-ray Spectrograph which analyzes specimens for as many as 24 elements, giving qualitative and quantitative information on a printed tape.

For your free copy, write directly to the manufacturer.

Ultrasonic Joining

Strength and Corrosion Resistance of Ultrasonically Soldered Aluminum Joints. J. B. Jones and J. G. Thomas, Aeroprojects Inc. for Frankford Arsenal, U. S. Army. March 1956. 61 p. (Order PB 121965 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1.75.) A variety of tin-base, cadmium-base, and zinc-base solders—32 in all—were effective in the fluxless tinning of aluminum by ultrasonic techniques. Specimens of 2024-T3 Alclad aluminum were prepared with each of the solder alloys and subjected to alternate immersion in 3.5% sodium chloride solution. The best solder, an alloy of 95% zinc and 5% aluminum-silicon eutectic, showed essentially no loss of strength after 900 hr of alternate immersion. Other solders containing 14% zinc or greater alloyed with tin and/or aluminum showed comparatively good resistance in the salt-solution environment. The solders which were most effective during earlier immersion in distilled water displayed poor resistance in the salt-water environment. Correlation of the data obtained in the two environments indicated that solders must be specifically selected for the environments in which they are to be used.

Ultrasonic Welding of Metals. J. B. Jones, C. F. DePrisco, and J. G. Thomas, Aeroprojects Inc. for Frankford Arsenal, U. S. Army. April 1955. 105 p. (Order PB 131084 from OTS, U. S. Department of Commerce, Washington 25, D. C., $2.75.) Significant improvements in welding equipment and techniques are claimed in this final report of an investigation of the possibilities of the ultrasonic process for joining similar and dissimilar metals. Results indicated that the technique has a potential for a wide range of metal joining problems. Among the achievements were successful welds in gages of 1100 aluminum through 0.062 in. and in several other metals and alloys. Shear strengths of the welds equalled those of the materials themselves. No reduction in strength was observed after about 5000 hr exposure in each of two corrosion environments. Grain orientation in the materials to be welded was found not significant. Surface films adversely affected weld strength, and polished surfaces seemed more readily weldable than rough surfaces. Based on the results of the study, recommendations are made for further development of the ultrasonic process, with emphasis on improvement of the elastic vibratory energy system, and identification of the mechanism of the process.

The Application of Ultrasonic Energy to Cold Welding of Metals. J. B. Jones and C. F. DePrisco, Aeroprojects Inc. for Frankford Arsenal, U. S. Army. Nov. 1953. 61 pages. (Order PB 131083 from OTS, U. S. Department of

(*Continued on page 26-8*)

PREHEATING—RESIDUAL STRESSES—STRESS RELIEVING

Summary of remarks made at the 2nd World Metallurgical Congress, Hotel Sherman, Chicago, Nov. 5, 1957

BY W. SPRARAGEN

We have heard a number of talks on various aspects of this subject and some of the audience may be a bit confused at the seemingly contradictory remarks. I will attempt to clarify a few of the points involved, and, unfortunately, may cause even greater confusion than existed before.

Residual Stresses and Stress Relieving

Residual stresses exist every time a weld is made and generally, locally at least, these stresses are nearly always of yield-point magnitude in one or more directions. Are they harmful? That all depends on the circumstances. The Ship Structure Committee has prepared a book on this subject[1] and obviously one cannot in a few minutes cover the entire subject. Therefore, to narrow the topic for discussion we will exclude from consideration the general residual or "reaction" residual stresses. These definitely must be considered by the designer and fabricator, and reference is again made to the above-mentioned book.

Again, for the sake of simplicity, we will exclude cases where dimensional stability or stress-corrosion are involved, as obviously in such cases, residual stresses should be reduced. This now leaves us with consideration of local residual stresses and what to do about them, say, in field-erected structures. In shop-fabricated pressure vessels, particularly over 1¼ in. in thickness, experience has shown that furnace stress relieving is very beneficial in lowering peak hardness and in restoring notch toughness and, of course, in reducing residual stresses. It is generally agreed that the term *thermal stresses-relief treatment* in such cases was unfortunate indeed. A more appropriate title would have been *post weld thermal treatment*.

The Welding Research Council, the Ship Structure Committee and many others have made tests, using both large and small specimens, involving biaxial and triaxial residual and load stresses. In the absence of a serious flaw or design stress concentration, no evidence has been produced that static load stresses can make such a structure less useful than one which does not have residual stresses. The only exception has been in reduction of load carrying capacity of columns because of secondary stresses. There is still an element of doubt whether or not in cases of impact loads residual stresses will cause trouble if the structure were operating below its nil-ductility transition temperature.

The primary reason for the above statement is that any load stresses at a particular point where there are high residual stresses cause plastic flow to take place and the residuals are generally reduced by the amount of load stresses at that particular point. Then why worry about residual stresses?

Now, if we have a serious flaw or a severe stress concentrator, the story may sometimes be different. Please keep in mind that residual stresses may either expedite or retard plastic flow. If we have a severe stress concentrator due to design, workmanship or other reasons, strains due to load stresses become concentrated in a very small region. If, at the same time, we have high local residuals at this point, plastic flow is inevitable if possible. If we are operating above the transition temperature of the structure, at that point the stress may be sufficiently large to reduce the stress concentration by dulling the notch so to speak, or if all the ductility has been used up, the stresses are relieved by a crack. If, however, we are operating below the nil-ductility temperature of the metal in the structure at that particular point, very little plastic flow uses up whatever ductility is left and a brittle crack is on its way. Therefore, residual stresses which tend to expedite plastic flow may use up the remaining ductility at a much lower load stress than would be the case if such residual stresses were not there.

What to do about residual stresses in field-erected structures—The Welding Research Council has written a book on it entitled "Control of Steel Construction to Avoid Brittle Failure." As some of the speakers have stated, the main answer lies in good design, fabrication procedures and selection of materials having a low transition temperature. In the use of heavy-walled vessels for nuclear work, engineers in this country and abroad have utilized some forms of thermal stress-relief treatments in the field.

Will mechanical stress relief do as well? Mechanical stress relief such as a hydrostatic test of a simple structure may release residual stresses if carried out at warm temperatures. In complex structures at points of stress concentration, it may introduce new residual stresses. In any event, mechanical stress relief will not improve notch toughness.

Preheating

What about preheating? In a number of tests such as hatch corners and impact tests on heavy butt-spliced beams, preheating gave lower transition temperatures than did stress relieving. Small laboratory specimens showed that preheating reduced rate of cooling, so that microcracks did not form. If such microcracks did form, then post-heating could not heal them. Carefully moisture-controlled conditions with low-hydrogen electrodes also avoided these microcracks.

One speaker has stated that it is not necessary to preheat low carbon (under 0.25) plate for welding. This brings out that preheating is sometimes used even in such cases where severe restraint is involved, to prevent cracking. Other methods are low-hydrogen electrodes and peening.

We must, therefore, conclude that yes and no general answers in regard to these three subjects cannot be given, which would be universally applicable. Experience and good engineering judgment must be utilized in handling the problems involving preheating, stress relieving and residual stresses.

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[1] Osgood, W. R., "Residual Stresses in Metals and Metal Construction." Published by Reinhold Publishing Co., New York.

SAFEGUARDS ASPECTS OF REACTOR VESSEL DESIGN

Authors indicate that a pressure vessel for a power reactor requires a more comprehensive control of design, materials and fabrication than is employed in conventional pressure vessels

BY D. R. MILLER AND W. E. COOPER

SYNOPSIS. The problem of design of power-reactor vessels for safety and durability requires careful application of existing industrial experience and engineering fundamentals to assure adequate consideration of the new problems which arise. Internal heat generation in structural materials, radiation-induced changes in mechanical properties, thermal shock and strain cycling, and coolant-dissociation effects on corrosion and embrittlement all present problems which require close attention. The hazards of mechanical failure and the cost and difficulty of repair place a high value on safety and reliability and justify comprehensive structural-design criteria and evaluation coupled with close control of material and fabrication quality.

An uncommon problem associated with the pressure-vessel design is analysis of the consequences of conceivable accidents due to reactor runaway, or in some cases due to a nondetonating chemical reaction. In some cases a pressure-tight building is provided to prevent spread of radioactivity. The problem of penetration of the enclosure building by missiles from the pressure vessel then requires careful evaluation.

Introduction

The discussion presented here deals with the problem of design and the problem of hazards evaluation of vessels for power reactors. Atomic power reactor vessels usually present greater difficulty in design and greater potential hazards than vessels for other types of reactors.

There is a great variety of reactors which can be designed for power production, and there is a wide variation of operating conditions to be met by reactor power systems. However, reactors with large power capacity have certain common characteristics. All contain, during part of their fuel consumption cycle at least, sufficient radioactivity in fission products to present serious hazards if the radioactivity is released. Reactors operating at high rates of heat production per unit mass of fuel are subject to the possibility of release of fission products in case of loss of coolant, either immediately with liquid or slurry fuel-coolant systems or after melting of solid fuel. Loss of coolant may occur through small leaks or as a result of a major rupture.

The quality attained in mechanical design, control of corrosion, materials and fabrication are the major factors in preventing the occurrence of small leaks. The quality of the scientific and engineering effort in design of the power-plant system, components and control and safety system, and the quality of operation and maintenance of the plant will largely determine whether major ruptures will occur.

While the discussion here is directed primarily at design of reactor pressure vessels, much of the discussion is pertinent to other components of the primary coolant system.

The Industrial Background for Design

One responsible for establishing a code for design and fabrication of a reactor pressure vessel must decide whether an existing design and fabrication code will be satisfactory. If no existing code is considered adequate, he must establish one which makes a satisfactory compromise among numerous factors. At the outset he should recognize that absolute reliability cannot be achieved, and that existing codes meet specific objectives for specific types of apparatus by employing design and fabrication practices based on experience. Inherent in existing codes is recognition of the critical factors in design of a particular type of apparatus and cognizance of the hazards and costs of mechanical failure. It therefore is in order here to examine the development of atomic-power systems in the light of industrial experience.

The development of power reactors presents a situation which is unusual in the evolution of power apparatus. This new source of power is being brought quickly from birth to maturity instead of slowly by an evolution beginning with small, low-capacity, low-efficiency, relatively low-cost units that have been built in the initial stages of development of earlier power sources. Consequently, an unusual emphasis must be placed on engineering and scientific fundamentals in design to substitute for experience which has been gained at moderate cost during evolution of earlier power sources. Because of the huge investments characteristic of power reactors, and their unusual hazards, experience through trial-and-error methods would be prohibitively expensive. With the years required for design, construction and proof of reliability of a power reactor, progress would be seriously delayed if trial-and-error methods were employed without success.

Perhaps the single factor which has contributed most to the industrial technology and high standard of living enjoyed by most of the world today is the availability of structural materials which have a large capacity for absorbing punishment. If all metals were brittle, apparatus would be much more cumbersome, and far more comprehensive design engineering would be required to assure reliability. With the ductile materials available to us it is often possible to employ simple design rules or trial-and-error methods.

As the technology of mechanical design has progressed we have learned more and more about the capacity of structural materials to absorb punishment. Much is now known about static yielding and fracture phenomena under complex states of stress. Much is also now known about the resistance of metals to cycling of stresses for millions of cycles. Reliable design practices and codes have been established for static or infrequently cycled

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loads and for millions of cycles of constant intensity. Much attention is currently being given to the intermediate range where design for static loading is not adequate, but where it is not practicable to limit local stresses to the endurance limit. It may be safe to design some atomic-power plants on a static-load basis; however, depending upon the characteristics of the plant or its application, cycling of pressures and temperatures may place the design in the intermediate range with respect to fatigue.

One of the most important problems in a new engineering development is the recognition and evaluation of the new problems which arise or the new significance of old problems which have been encountered in industry. Some of the new problems are recognized readily because of their close association with the fission process. Most likely to be neglected are old problems about which engineers have become complacent, because they have not required comprehensive treatment in design of conventional apparatus. Thermal stresses lie in the latter category. Only recently have there been comprehensive studies of the ability of metals to withstand cycling of thermal strains.[1]

If the economic and technical aspects of design could be evaluated precisely, the greatest profit and industrial progress would be made by the manufacturer making an optimum compromise between the costs of design, materials and fabrication on the one hand and the performance of his product on the other hand. For the purposes of the present discussion we neglect here the cost of marketing the product and other nontechnical factors. Precision in economics and engineering is not generally attainable. However, industry does attempt to achieve a proper balance between the opposing factors. It is for this reason that all engineering aspects of industrial apparatus are not routinely given comprehensive treatment. Industrial practices have been established to give adequate quality of design and manufacture in those areas where judgment and experience show the need for close control of quality. Development of an entirely new source of power warrants close examination of established practice to determine its suitability to cope with the new problems which arise.

Some design practices are established to protect the public interest from the standpoint of safety. The Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers is an example of this type of Code. It prescribes rules for design, fabrication and inspection with the objective of assuring safety against explosion hazards. Adherence to the Code does not assure long-term reliability of a pressure vessel for all types of service. The limited scope of the Code is illustrated by the following excerpt from page 99 of Section VIII (1956) of the Code, which is applicable to unfired pressure vessels:

"... it is a basic principle that the Code rules are intended to provide minimum safety requirements for new construction, not to cover deterioration which may occur in service as a result of corrosion, instability of the material or unusual operating conditions such as fatigue or shock loading."

In connection with the exclusion of consideration of fatigue damage it is noteworthy that Section VIII of the ASME Code prescribes for thermal stresses a limit only on the membrane component in combination with effects of other loads. (See paragraph UG-23 (b) of Section VIII of the ASME Code, 1956)

There is a continual advancement in industrial design practices and design codes paralleling advancements in engineering technology. These advances have permitted growth in the performance achieved by industrial apparatus. Contributing factors have been improved materials, more knowledge of their mechanical behavior, improved control of quality of materials and lower and more rationally established safety factors. A major contribution to these advances is the work of the British Welding Research Association and the Pressure Vessel Research Committee of the Welding Research Council.

It is of particular interest in noting progress in the field of power-apparatus design that the 1955 edition of the American Standard Code for Pressure Piping[2] now employs a much more rational basis for limitation of thermal-expansion stress than was formerly employed. The following quotation of paragraph 620(h) of the previous edition[3] shows the need for improved fatigue criteria.

"Where a piping system is subject to temperature changes of a definitely cyclic nature or to severe vibration that may result in failure by fatigue, the limit of the safe combined stress permitted in paragraph (g) shall be divided by 2."

The new edition places limits on the range of thermal-expansion stress which depend on the number of cycles of temperature variation expected. The highest allowable-stress range is applicable to systems which are designed for 7000 cycles or less. Allowable-stress reduction factors are specified for more frequent cycling.

Now let us summarize some of the new factors which must be taken into account in establishing practices for evaluation of reactor-pressure-vessel design problems, and for control of stress levels and quality of material and fabrication.

1. Reliability has a higher value in the first unit of a prototype of a basically new type of power plant, because its operation provides a check on quality of design and fabrication. A gamble which failed to pay off in a prototype would call for further time-consuming development with consequent delay in utilization of atomic energy.

2. The difficulty of decontamination and repair or replacement of a reactor pressure vessel might inactivate a huge investment for a much longer time than would repair or replacement in a conventional power system.

3. The potential hazards to operating personnel, the public and property are much greater than with conventional power plants.

4. Radiation damage to structural materials may impair their mechanical properties.

5. Dissociation of coolants (water in particular) may aggravate corrosion and hydrogen embrittlement problems.

6. Unusually-severe thermal transients can occur, particularly due to emergency shutdown, in reactor systems employing a large temperature rise of coolant through the reactor. A large temperature rise is usually used when liquid metals or gases are employed as coolants.

7. Thermal stresses during normal startup and shutdown often require particular attention, because the vessel configurations employed often have regions of slow thermal response in complex structures and have stringent requirements on dimensional stability.

8. Internal heat generation in the pressure-vessel wall is a new problem. It may produce high thermal stresses which will be particularly significant in systems subject to frequent cycling of load. This problem is of most concern in heavy walls of vessels for gas- or water-cooled reactors.

In view of the above new considerations, it appears essential that a comprehensive basis for control of stresses, corrosion and quality of materials and fabrication be employed. The increased investment in engineering, materials, fabrication and inspection will undoubtedly be repaid in full measure by the increased safety and reliability which will be attained. While no industrial pressure-vessel code is sufficiently comprehensive to cover all aspects of reactor pressure-vessel design and fabrication, it is to be expected that suitable codes will be established in the future.

Comprehensive Structural-Design Basis Proposals

In the past several years there have been substantial efforts towards the development of more rational and exacting structural-design bases, particularly

for vessels to be used in critical service. Recent papers by Murphy, Soderberg, and Rossheim[4] review pressure-vessel design practices and problems and indicate tentative basic principles for revision of the ASME pressure-vessel codes. Three classes of vessels are proposed. One of them is the "critical class." This class might be applied to reactor pressure vessels by virtue of their radioactivity hazards. The proposals of these authors include recognition of the different significances of steady-state and cyclic loadings and of membrane and local stresses.

Of particular significance to reactor-vessel design is the joint effort of the United States Navy Bureau of Ships, the Bettis Atomic Power Department (Westinghouse Electric Corp.), and the Knolls Atomic Power Laboratory (General Electric Co.) to develop a structural-design basis for naval reactor pressure vessels. A draft of this basis was originally circulated for comments in 1955 and is essentially summarized in Reference 5. A second, and substantially revised, draft was circulated in early 1957. A similar basis is now in use for certain naval reactor designs, and it is anticipated that formal adoption is forthcoming. This design basis is similar in many gross respects to the proposals of Reference 4, differing in details and in handling superposition of cyclic loadings of various intensities and occurrence frequencies.

Problems in Design Evaluation

In development of a new type of atomic power plant, component and system design and evaluation will proceed in parallel, since they are interrelated. This requires that good judgment and sufficient conservatism be used in prediction of system-operating transients for design of components. Thereafter the component designer must recognize all significant sources of stress and make an adequate evaluation of them. Some pertinent examples of structural analysis have been discussed by Horvay.[6]

Design of reactor power plant components often requires unusual care in calculation of temperature distributions because of the common occurrence of high steady-state or transient thermal stresses. Rapid thermal transients are inherent in reactor-protective (scram) systems, and reactor-control systems may readily be designed for rapid maneuvering of power. The effects of thermal-driving heads and vapor formation may be important in modifying temperature distributions in reactors and heat exchangers, particularly under low-flow conditions. An interesting and sometimes troublesome characteristic of reactors is the redistribution of heat production which occurs after a power transient due to delayed heating from fission products.

In seeking compliance with a design basis requiring limitation of local stresses to definite values, the pressure-vessel designer soon is hampered by the fact that many common problems have not yet been solved. A sound fundamental understanding of elasticity and good judgment is required to assure that stresses are not seriously underestimated. In many cases it will be necessary to do original theoretical or experimental work to evaluate problems.

Loadings Which Contribute to Potential Hazards

Any loading which may result in leakage from the vessel is a potential source of hazard. The more significant of these are: (a) coolant pressure, (b) cyclic operation, (c) earthquake (or shock loading in a mobile plant), (d) nuclear accident, and (e) chemical accident.

The first three of these loadings are those with which the designers of power plants are familiar, so they will not be discussed in detail here.

The possible causes of nuclear and chemical accidents and means for their prevention are beyond the scope of this paper. However, certain characteristics of these accidents are pertinent and will be discussed.

A very important point to be understood with regard to the dynamic aspects of the loadings which result from either a nuclear or chemical accident in a reactor is that the explosions which can be postulated reasonably have inherently more than an order of magnitude longer energy-release duration than conventional fast-reacting explosions. The detonation-wave velocities in large explosive charges are in the range of 14,800 to 28,000 ft/sec.[7] The duration of release of about 10^8 calories of energy from a centrally detonated 2-ft diam spherical charge (about 440 lb) of TNT would be on the order of 50 microseconds. The load application on the vessel would be abrupt with a pressure-rise time much smaller than 50 microseconds.

The value of 10^8 calories is a reasonable estimate of the nuclear-energy release attainable in the worst-possible accident in a compact reactor with highly enriched fuel. However, the nuclear excursion periods which can be attained are usually considered to be one or more orders of magnitude longer than 50 microseconds, being limited by the lack of means for producing large and rapid surges in reactivity. Consequently, the loading on the vessel will increase during the period of energy release, and shock-wave effects will be relatively unimportant.

In the case of a chemical reaction between uranium metal or fuel-element cladding and water, maintenance of the reaction requires mixing of the reactants by diffusion and other means, and the reaction would not be simultaneously initiated throughout the reactor core. Hence, such a reaction is evidently much slower than an equivalent energy release from a detonating explosive.

From the above discussion it should be evident that caution is in order in relating reactor-safeguards evaluations to "equivalent" detonations of chemical explosives. In particular, shock-wave effects will be much less significant in reactor accidents than in detonating explosions. The assumption of a detonation of the same energy release may lead to a faulty indication of the effects of the explosion and the protective measures which should be used.

Even though a reactor accident is much slower than a detonating explosion, the peak pressure developed in the pressure vessel may be developed in a time comparable with the radially-symmetric natural period of the vessel. In the elastic case this can lead to a transient doubling of deformation relative to that which would be produced statically by the same pressure. In a ductile vessel a suddenly applied pressure corresponding to a hoop stress equal to the yield strength under static loading would normally cause a small amount of plastic flow without risk of rupture. Under more intense loading, analysis of the effects of the pressure rise requires consideration of inertia effects and structural resistance to deformation in various directions and the effects of expansion on the reduction of pressure in the vessel. An example of techniques used in reactor-explosion analysis has been presented by Levedahl and Howerton.[8]

Ductile Fracture of Pressure Vessels

It is appropriate to recognize that the pressure vessel itself may be the source of a hazard. Rupture of the vessel may occur at one extreme as a small leak due to local fatigue failure with consequent escape of small quantities of radioactive coolant and no other consequences other than a long outage of the system and an expensive repair job. At the other extreme a fatigue crack may propagate slowly without leakage until it is suddenly propagated rapidly under the action of pressure loading, and gross rupture occurs. The consequences in the latter case can be melting of fuel elements and dispersal of fission-product activity as well as coolant radioactivity. The occurrence of local leakage appears much more probable than abrupt rupture, if proper materials, design and fabrication are used. The probability of any failure

of the vessel can be reduced by care in design in regions of stress concentration. The careful design of penetrations of the vessel is particularly important. Smooth contours and a gradual transition in thickness in pipe nozzles are very desirable.

A well-designed and fabricated steel pressure vessel can be expected to have a substantial capacity for withstanding pressures beyond the design value without gross plastic deformation or failure, except for ferritic steels at low temperatures. Meeting the ASME Boiler and Pressure Vessel Code hydrostatic-test requirement essentially assures initial ability to withstand a 50% overload pressure at design temperature without gross membrane yielding or fracture. If the vessel has not been subjected to significant fatigue, corrosion or embrittlement damage, it would be expected to maintain this resistance to pressure. The vessel also would be expected to be capable of withstanding overloads considerably above 150% of the design value with design in accordance with the ASME Code, and it would be expected that a substantial increase of volume could be attained without rupture, if there had been no impairment of mechanical properties of the steel.

An analysis of the extent of uniform plastic strain to be expected in deformation of either a cylindrical or spherical shell subjected to internal pressure is presented in Reference 9. The reference presents a discussion of the yield pressure, maximum pressure, strain at maximum pressure and the localization of deformation prior to rupture in terms of the initial dimensions of thin-walled vessels and the material properties of vessels made of ductile materials. In addition, design with brittle materials is discussed briefly and the influence of strain concentrations upon differentiation between brittle and ductile materials is discussed. The authors believe the theoretical results of the above paper to be a valid indication that, under favorable conditions, a pressure vessel is capable of a considerable amount of deformation before fracture.

Brittle Fracture of Pressure Vessels

The choice of material and the operating temperature may have a substantial bearing on the possibility of catastrophic fracture of the pressure vessel. There is an inherent advantage in austenitic stainless steels over ferritic steels, because in the annealed state they do not exhibit a low-temperature transition from ductile to brittle fracture. They also have a low notch sensitivity, presumably because of the local strain hardening which resists crack propagation.

The brittle-fracture characteristics of ferritic steels have been described by Pellini[10] in terms of a quantity designated as the "nil-ductility transition temperature (NDT)." It has been found that this temperature correlates fairly well with the temperature at the 20 ft-lb level of the Charpy V-notch impact test for carbon and very-low-alloy steels (such as ASTM A212) and with the 30 ft-lb level for more-highly-alloyed steels (such as ASTM A302). For a vessel as critical as a reactor vessel, it is the present authors' opinion that full operational pressure should not be applied at a temperature less than NDT + 30° F, and that the hydrostatic-pressure test (at 150% of maximum allowable working pressure) should not be applied at temperatures less than NDT + 60° F in vessels designed in accordance with Reference 5. Higher minimum temperatures are probably in order for vessels designed and fabricated to current industrial codes. Some decrease of these temperature margins is probably in order in the case of large forgings for which a significant number of specimens have been tested at critical locations.

There may be a significant risk of development of undetected internal cracks in a ferritic steel during hydrostatic testing at insufficiently-high temperature. Conditions may be conducive to development of a crack initiated at a minor internal defect, but they may not be conducive to propagation of the crack during hydrostatic test. Such a crack might be a source of concentration of cyclic stresses and premature fatigue failure.

With respect to the effects of fatigue damage in reducing deformation capacity, Coffin[1] has shown that plastic-strain cycling to a substantial fraction of the fatigue life makes a substantial reduction in the true stress and strain to fracture in a subsequent uniaxial tensile test. The reduction may be more significant under biaxial loading. If design is conservative with respect to fatigue, this factor will probably not be important. Its importance is likely to be reduced further by virtue of the fact that the regions of maximum fatigue damage are likely to involve local bending stresses. These regions are unlikely to be the regions of maximum membrane strain and consequently may not cause a substantial reduction in membrane strain to fracture. However, this factor contributes to the importance of conservatism in design with respect to fatigue.

A question which deserves investigation is whether fast-neutron irradiation raises the nil-ductility fracture transition temperature. It is expected that the temperature of the irradiation exposure will be an important variable in such an investigation. Some data with regard to this matter have been presented by Baldwin.[11]

Missile Effects

If the rate of pressure rise in an accident is sufficient to cause strains to the point of local fracture in a time short as compared with that for propagation of stress-relief waves around the half-periphery of the shell, fracture will occur in more than one region. If initial fracture of a cylindrical shell occurred along two generators at the ends of a diameter, and if at fracture the two semicylindrical shells had high velocity, the relief of applied pressure would not preclude the occurrence of additional fractures, because the initial velocity of the parts of each semicylindrical shell is radial rather than unidirectional. Forces must be sustained within the shell sufficient to change the radial velocities to a unidirectional velocity, or additional fracture will occur.

Velocities of large portions of a pressure vessel resulting from violent fracture can be estimated from energy considerations. In cases in which the authors have assisted in hazards evaluation, the velocities corresponding to the worst-possible reactor accidents have been on the order of a few hundred feet per second—about an order of magnitude slower than missiles which are commonly considered, i.e., those from gunfire or detonating explosives. Also, missiles from a reactor incident probably would be larger than those usually of interest in barrier-penetration problems.

The nature of missile damage will depend upon the nature of the barrier which resists missile penetration. The biological shielding may be a barrier sufficient to confine missiles from the reactor pressure vessel, or the shield structure may be incapable of withstanding the pressures existing after rupture of the vessel and may thus be another source of missiles.

The most satisfactory means for providing confinement of radioactivity is probably the use of a steel building designed as a pressure vessel such as has been proposed for a number of power plants now under development. A steel shell of large size can readily be designed to resist the pressure loading resulting from incidents far beyond the containment of a reactor pressure vessel, largely because of the rapid increase in volume with increasing diameter. Hence, while it may be impracticable to design a reactor pressure vessel to confine the worst-conceivable incident, it is practicable to design a steel building to confine such an incident, at least with respect to pressure-resisting capacity. However, one must consider the possibility of local penetration of the building shell by a sharp corner of a fragment of the pressure vessel or a gross rupture due to a fragment passing entirely

through the shell. With edge-on incidence, a piece of plate may penetrate the shell by local shearing and tearing. With parallel incidence at moderate velocity, the impact would cause a local bulge and strains distributed over a substantial area of the shell would absorb the kinetic energy of the missile. By moderate velocity here we refer to velocities much lower than the velocity of plastic-stress waves in the steel shell. We also refer in the case of parallel incidence to missiles whose major dimensions are much larger than the thickness of the missile.

The resistance of a steel shell to penetration by edgewise-incident missiles from a violently-fractured pressure vessel can probably be increased considerably by the use of an interior coating of a couple of inches of concrete reinforced with steel mesh. The concrete will offer additional resistance to penetration and will distribute the local loading over larger areas of the steel shell. Alternatively, it may in some cases be preferable to provide missile barriers separated from the containment building itself.

The above discussion of missiles is considered appropriate in view of the common use or proposal of pressure-tight enclosures around reactor power plants. The authors do not mean to imply that such enclosures are without disadvantage. There may be an increased risk of occurrence of a severe accident as a consequence of system complications introduced by use of a pressure-tight enclosure, particularly if the plant is operated by personnel outside the enclosure. If operators work inside the enclosure, there may be increased hazard to the operators in case of some otherwise minor accidents.

The authors urge presentation to the technical societies of papers reporting the diagnosis and effects of explosion accidents. Such data are of considerable value in making a realistic appraisal of the probable consequences of potential power-reactor plant explosions and are helpful in design of protection against missile damage. An interesting summary of boiler and pressure-vessel failures has been presented to the Institution of Mechanical Engineers by Eyers.[12]

Conclusion

The authors conclude that a pressure vessel for a power reactor requires a more comprehensive control of design, materials and fabrication than is employed in conventional pressure vessels, which entail lesser hazards, cost and difficulty of repair.

Well designed and fabricated pressure vessels can be expected to have a substantial overload capacity to resist accidental, abnormal pressures and can be expected to deform without rupture sufficiently to enable a substantial core-and-coolant expansion. This deformation affords a means for reducing reactivity and limiting the energy release of a nuclear accident.

It appears practicable to provide a high degree of reliability against rupture or missile penetration in a steel building designed as a pressure vessel for confinement of power-reactor incidents.

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RESEARCH NEWS

(Continued from page 20-s)

Commerce, Washington 25, D. C., $1.75.) Ultrasonic spot and seam welding was successful in non-ferrous sheet materials in 0.005-inch and 0.010-inch gages without the use of elevated temperatures. Ultrasonically spot-welded 28 aluminum developed adequate strength and pressure-sealing characteristics in reasonable ultrasonic exposure time and at reasonable power levels. Internal deformations of the faying surfaces were present, but no comparable external indentation occurred. No corrosion effects were evident after 2000 hours of exposure to salt water or to aerated distilled water at 95°C. Preliminary experiments indicated that other metals, particularly brass, copper, and gilding metal, can be ultrasonically welded.

Radiation

Symposium on Radiation Effects on Materials. ASTM Special Technical Publication 208. 196 pp., hard cover. 6 × 9 in., $4.75. This symposium is the first of a series sponsored jointly by ASTM Committee E-10 on Radioisotopes and Radiation Effects and the Atomic Industrial Forum. It was presented at the ASTM 2nd Pacific Area National Meeting, Los Angeles, Calif., September 1956. The symposium is divided into three parts: (1) Theory of Radiation; (2) Radiation Facilities and Mechanics of Testing; and (3) Experimental Tests and Results on (a) Fuel and Graphite Materials, (b) Structural Materials, including Organics.

The data and evaluations presented are made as a contribution to the understanding of existing code and specification values as they apply to nuclear-reactor structures and components. The known properties of materials must be evaluated in the light of the actual reactor, operating conditions. By adapting and interpreting the vast backlog of data on unirradiated materials with the sparse but accumulating knowledge of irradiated materials, cautious extrapolation within the limits of experimental work can be allowed.

This symposium will be of especial value to those interested in the design and operation of nuclear reactors. Following the introduction, the three parts contain a total of 16 papers, most of them accompanied by discussion. The book contains numerous tables of data and is well illustrated with photographs, diagrams and graphs. Several of the papers have bibliographical references.

Copies of this book may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., at $4.75 a copy.

EFFECT OF PREHEATING AND POSTHEATING ON TOUGHNESS OF WELD METAL

Test program set up to investigate the effects of preheating and postheating on the transition temperature for weld metal from seven classes of steel electrodes

BY T. N. ARMSTRONG AND W. L. WARNER

Preheating and thermal stress-relieving treatments are not always applied to weldments primarily to reduce the level of residual stresses but quite often are employed to improve the microstructure of the weld heat-affected zone of the base material. Such thermal treatments will, in many instances, result in lower temperature of transition from ductile to brittle behavior and, although it is recognized that for certain applications residual stresses must be at a minimum for satisfactory performance, it is still to be proved that residual stress has much influence on transition temperature.[1]

The effects of preheating and postheating on transition temperature have been investigated for quite a variety of steels,[2] but the effects of such treatments on weld metal are not so well known, as there is still some controversy as to whether such treatments are beneficial.

Classes of Electrodes Tested

To obtain additional information on the subject, a test was initiated in the research laboratory at the Watertown Arsenal to investigate weld metal from a number of classes of steel electrodes. The electrodes selected were $^5/_{32}$-in. diam of E6010, E6013, E6020, E7015, E8015-C2, E8018-C2 and E10016. The electrodes were obtained from commercial stocks and are believed to be representative of each class.

Preparation of Specimens

Single-V butt welds were made in 1-in. plate using about 180 amp on the root pass and approximately 220 amp on subsequent passes. When preheat was applied, the interpass temperature was not permitted to exceed the initial preheat temperature by more than 100° F.

After welding, and after postheating when applied, Charpy specimens were prepared by machining pieces so that the long axis of the specimens was at right angles to the direction of welding and with the weld located in the center portion of the specimen. Standard V notches were then machined in the approximate centerline of the weld and normal to surface of the plate. Specimens from each weld were then broken at different temperatures in the Charpy impact machine and the absorbed energy-temperature curves plotted for each weld.

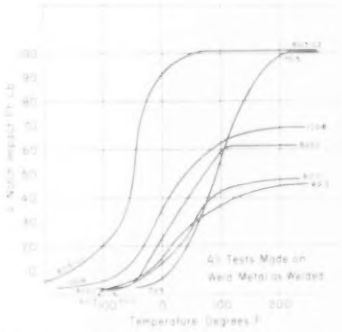

Fig. 1 Charpy-impact transition curves for weld metal from six classes of electrodes

Results of Postheating

The transition curves for weld metal in the as-welded condition from six classes of electrodes are shown in Fig. 1. As would be expected the transition temperature for the $3^1/_2$% nickel-steel weld metal, E8015-C2, is considerably below that for any of the other welds. The E10016 (Ni-Mo-V) weld is next in order of merit. The E6020 was definitely the best of the unalloyed steels and the other three carbon steels fell within a rather narrow scatter band. The impact values for E7015 were somewhat lower than normally expected in the vicinity of 0° F.

A second series of tests was made on specimens from the same welds after stress relieving at 1105° F for 1 hr and cooling in air. These results were plotted together with the results for the as-welded condition in Fig. 2. Results for the E8018-C2 (low hydrogen, iron powder, $3^1/_2$% nickel steel) weld metal were available somewhat later and are shown in Fig. 3.

It should be noted that the effect of postheating (stress relieving) on the impact values for the weld metal varies considerably for the different electrodes. The E6010, E7015, E8015-C2 and the E10016 show very decided susceptibility to temper embrittlement, E6013 and E8018-C2 show practically no susceptibility and E6020 only a moderate degree. It is observed that the impact values are higher for five of the seven electrodes in the ductile temperature range, but in no instance did postheating improve the impact values at the lower test temperatures. If the transition temperature is arbitrarily selected as the temperature at which 20 ft-lb is obtained, in no instance did postheating lower the transition temperature.

Effects of Preheating

Two electrodes, one of which was carbon steel E7015 and the other $3^1/_2$% nickel steel E8015-C2, were selected to determine the effect of preheating on the transition temperature of weld metal. The welds were made under the conditions previously described except that this series for each electrode consisted of welding with no preheat, and with preheat and interpass temperatures of 200, 400 and 600° F. The results of impact tests on weld metal from the E7015 electrodes are shown in Fig. 4 and for the E8015-C2 electrodes are shown in Fig. 5.

Preheat improved the impact proper-

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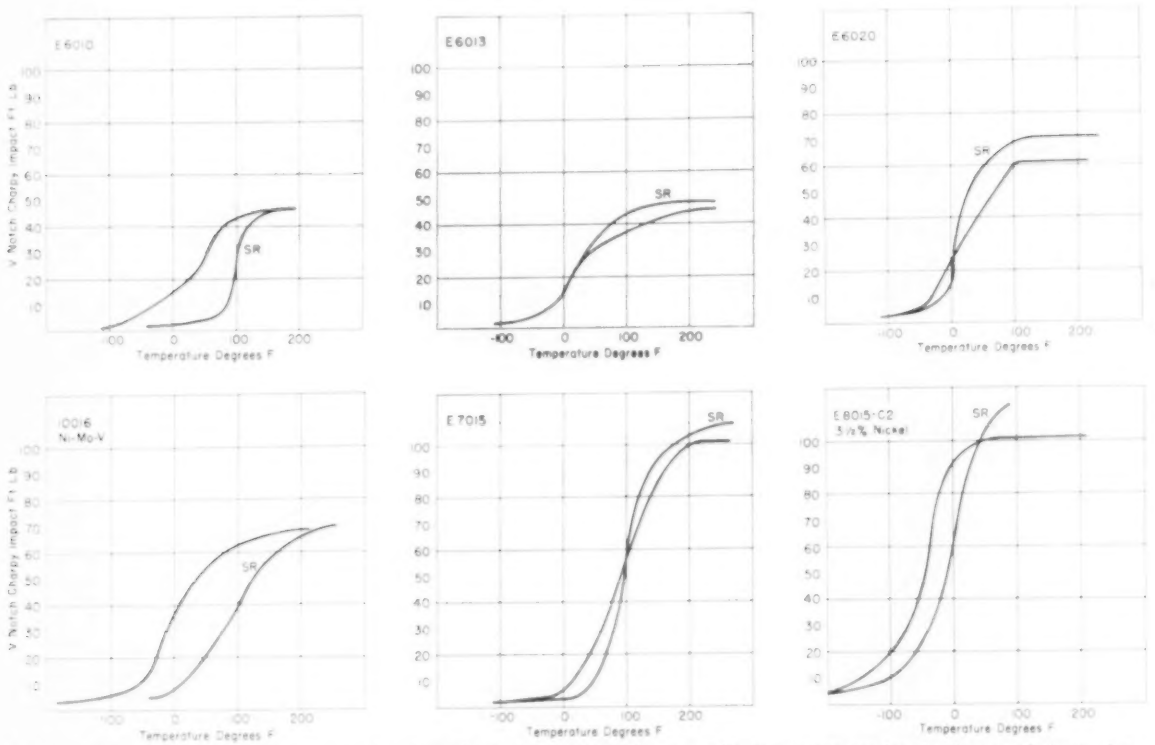

Fig. 2 Charpy-impact transition curves showing effect of conventional stress-relieving treatment for six classes of electrodes

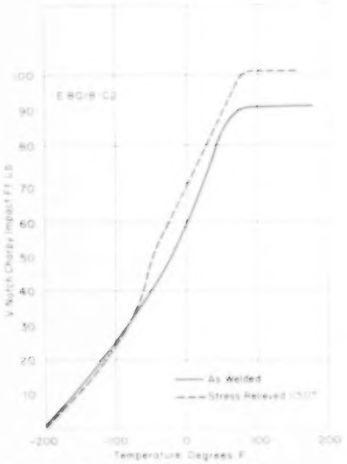

Fig. 3 Charpy-impact transition curves for weld metal from low hydrogen, iron powder, 3½% nickel-steel electrodes, E8018-C2

ties of the E7015 welds, but the magnitude of the improvement varies. The improvement associated with 200° F preheat faded out at about −50° F, but the improvements associated with 400 and 600° F preheats persisted down to almost −100° F. The values obtained with 600° F preheat were inferior to those resulting from 400° F preheat.

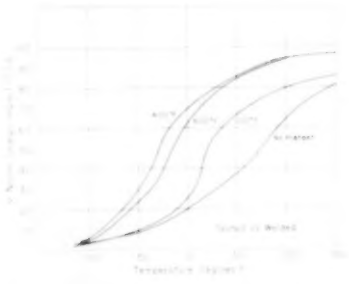

Fig. 4 Effect of preheat on impact properties of E7015 carbon-steel weld metal

Fig. 5 Effect of preheat on impact properties of E8015-C2 nickel-steel weld metal

The nickel-steel weld metal E8015-C2 reacted to preheat somewhat differently. Improvement in impact values was obtained at test temperatures down to about −150° F with 200 and 600° F preheats but improvement only to about −50° F resulted from 400° F preheat. Additional data are needed to determine if this is a peculiarity of nickel-steel weld metal or an experimental variable.

The two families of curves are assembled for comparison in Fig. 6. There is indication that the curves for each steel would fall within a closed loop if testing were extended over a sufficiently-wide range of temperature. This would mean that at temperatures where the steel is completely ductile

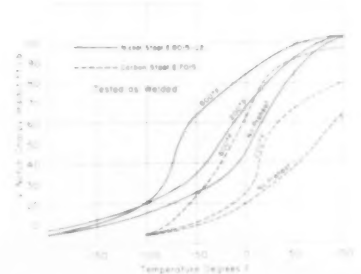

Fig. 6 Comparison of effect of preheat on carbon-steel and nickel-steel weld metal

and at temperatures where the steel is completely brittle, preheating has little or no effect on impact properties but, at temperatures between these extremes, preheating does improve the impact values of weld metal from these two electrodes.

Conclusion

1. Postheating weld metal from seven classes of steel electrodes at 1150° F in no instance effected a lowering of the transition temperature and four of the seven welds showed some degree of embrittlement resulting from the thermal treatment.

2. Preheating at temperatures up to 600° F improved the impact properties of E7015 carbon-steel weld metal and E8015-C2 nickel-steel weld metal. In no instance did preheating adversely affect the impact properties of welds from these two electrodes.

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1. Parker, Earl R.: "Stress Relieving of Weldments," THE WELDING JOURNAL, **36** (9), Research Suppl. (1957).

2. Stout, R. D.: "The Preheating and Post Heating of Pressure Vessel Steels," THE WELDING JOURNAL, **32** (1), Research Suppl. (1953).

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CONTINUOUS COOLING TRANSFORMATION CHARACTERISTICS OF THREE TYPES OF WELD METAL

Continuous cooling transformation diagrams are presented for Types 180, 230 and 260 weld metals. Differences in transformational behavior and microstructures are discussed in terms of alloy content

BY E. F. NIPPES AND E. C. NELSON

Introduction

Comparatively little experimental work has been done on the sub-critical transformation behavior of weld metals because of the experimental difficulties caused by the rapid transformation characteristics of these low-hardenability steels. The data presented in the literature[1,2] were obtained for homogenized samples, and cannot be regarded as accurately representative of the actual behavior of the weld metal in actual welds.

In the present investigation use has been made of a high-speed dilatometer capable of covering a range of cooling rates wide enough to include all of the important sub-critical transformations which occur on the continuous cooling of low-alloy and high-alloy weld metals.[3] Three types of weld metal were chosen to represent different composition ranges in current use.

Materials

The electrodes used in this investigation were procured from commercial sources and conformed to MIL-E-986 specifications. Three types of electrodes were used in this study: Type 180, Type 230 and Type 260. All were $^{3}/_{16}$ in. diam, and were operated with d-c reverse polarity at the optimum currents and voltages recommended by the manufacturers. All electrodes were baked at 600° F in a circulating-air furnace for a minimum time of 1 hr immediately prior to welding.

Specimen Preparation

Weld-metal pads, 1 in. wide by $1^{1}/_{2}$ in. high, were manually deposited on mild steel plates using a multiple-bead technique with weaving restricted to twice the electrode diameter. Particular care was taken to clean slag completely from the weld beads between passes. The completed weld pads were sawed from the base plates and machined into $^{1}/_{2}$-in. square bars. Only one bar was cut from each weld pad, and the pads were machined in such a manner to locate the bars as closely as possible to the tops of the weld pads in order to avoid the regions of the weld-metal pad which had been contaminated by molten base metal. Chips for chemical analysis were collected during the final machining operation on the $^{1}/_{2}$-in. square bars. High-speed dilatometer specimens, 0.7 in. long, were then machined from the square bars.

Experimental Procedure

The as-machined specimens possessed the segregated dendritic structure formed during the solidification of the weld metal. Austenitization of the specimens would tend to homogenize this structure by diffusion, and thereby cause the transformation characteristics to vary from those of the as-deposited weld metal. Because the object of this investigation was to determine as nearly as possible the transformation characteristics of the as-deposited weld metal, the austenitizing conditions were carefully chosen to retain the segregated character which the weld-metal austenite possesses immediately after deposition from the welding electrode.

An austenitizing temperature of 1800° F was chosen as experimentally convenient for this purpose. The specimens were held at this temperature just long enough to convert them completely to austenite without appreciable homogenization, and then quenched. The proper austenitizing time for each type of weld metal was established through metallographic examination of quenched specimens.

For each type of weld metal, a rough curve was derived from data obtained by repeated heating and quenching of a few specimens. Inevitably, such repeated austenitization tended to homogenize the specimens and cause their transformation characteristics to change gradually as their total time at 1800° F increased. This effect, however, was not appreciable in regions of the transformation diagrams where the transformation temperatures did not change radically with slightly different cooling rates.

Once the transformation characteristics of the steel had been established with the rough curve, a final curve was derived from data obtained on heating and quenching specimens just once, so as to approximate as closely as possible the behavior of the as-deposited weld metal. Such standard time-temperature-transformation diagrams are given for each of the three types of weld metal investigated.

The TTT diagrams also have been transposed into transformation temperature-cooling rate diagrams. During some of the transformations, the heat of recalescence accompanying transformation occurred within the 1300-1100° F temperature range. This caused discontinuities in the time-temperature curves in the region where the time to cool from 1300 to 1100° F is read. In order to preserve this criterion of cooling rate for comparisons involving both weld metals and base metals, the curves were extended as normal cooling curves past the point where the heats of recalescence first caused the curves to deviate from normal. The times to cool from 1300 to 1100° F were then read from the extended curves.

This method of obviating the effects of heats of recalescence on cooling rates can be justified on the grounds that a marked thermal arrest will occur only in a uniformly-cooled piece of steel,

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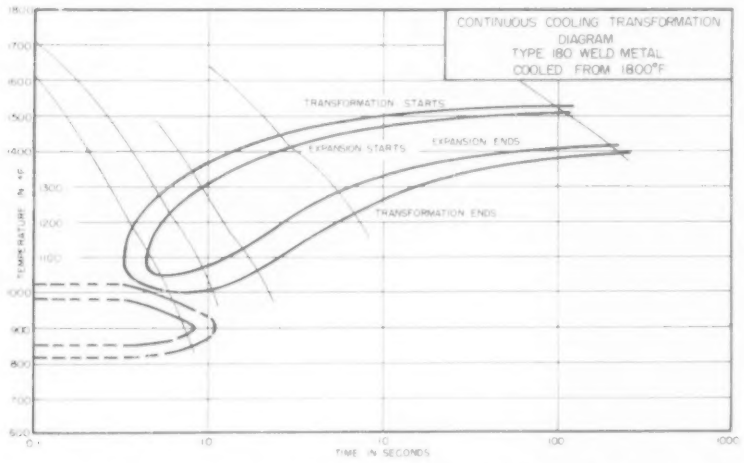

Fig. 1 Continuous cooling transformation diagram for Type 180 weld metal cooled from 1800° F

such as high-speed dilatometer specimen. In cases where a thermal gradient is present, such as in a weld, thermal evolutions will occur in succeeding differential volumes and will be dissipated by heat transfer from each transforming differential volume to adjacent non-transforming volumes. In addition, it may be seen from the TTT curves that transformations which are accompanied by heat evolution in the 1300-1100° F temperature range invariably are relatively insensitive to cooling rate. That is, the curves indicating the temperatures of the beginning and end of such transformations are relatively parallel to the time axis, and any error in computing the cooling rate under these circumstances will not cause an appreciable error in the predicted temperatures of the beginning and end of the transformations.

Experimental Results

Type 180 Weld Metal

The chemical analysis of the weld-metal pad was as follows:

% C	% Mn	% P	% S	% Si
0.08	0.60	0.020	0.035	0.34

% Ni	% Cr	% Mo	% Cu
0.10	0.05	0.01	0.13

This analysis corresponds closely to the composition claimed by the electrode manufacturer and can be considered for purposes of comparison as corresponding nominally to a plain-carbon steel of SAE 1010 grade.

The specimens were austenitized in the dilatometer for 1 min at 1800° F. These austenitizing conditions were sufficient to transform the specimens completely to austenite but did not result in appreciable homogenization of the cored dendritic structure produced during welding.

If this weld metal is considered as a plain-carbon steel of SAE 10XX grade, its continuous cooling transformation behavior can be expected to resemble, in general outline, Fig. 14 of Reference 4. Figure 1 shows that this is indeed the case. There are two distinct and separate temperature regions of transformation. In the upper temperature region, the transformation products are ferrite and carbide; in the lower temperature region, the transformation product is martensite. There is a range of cooling rates which produces a "split" transformation structure containing both martensite and ferrite plus carbides, but there is a definite temperature gap between the transformation ranges under these conditions.

The low-carbon and alloy contents of this steel could be expected to result in an extremely fast critical cooling rate. In addition, because of the segregated nature of the austenite, the true critical cooling rate of the dilatometer specimens was determined by the hardenability of the least hardenable segregated areas. A completely martensitic structure was not produced in any of the high-speed dilatometer specimens because of this. A few attempts were made using special thin-walled specimens, and enough information was obtained concerning the "split" transformation region to locate the transformation temperatures with good accuracy in this range of cooling rates. Figure 2 shows the structure of one of these dilatometer specimens which was cooled almost as fast as its critical cooling rate. A small amount of ferrite is visible at the boundaries of the martensite grains.

The temperature range over which high-temperature transformations occur in the "split" transformation region is greater than normal for a steel of this composition because of the segregated nature of the structure. The beginning of transformation corresponds to the precipitation of low-carbon, low-alloy ferrite from the inhomogeneous austenite, while the end of the transformation corresponds to

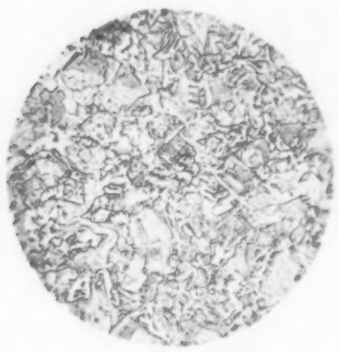

Fig. 2 Microstructure of dilatometer specimen of Type 180 weld metal. Time-to-cool from 1300 to 1100° F, 0.15 sec. Structure is ferrite and martensite. 0.5% nital etch, X 500

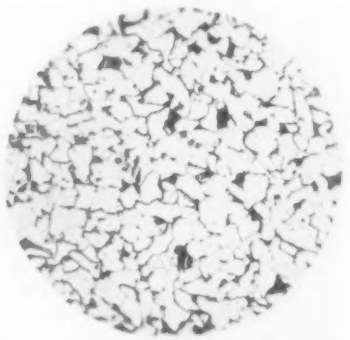

Fig. 3 Microstructure of dilatometer specimen of Type 180 weld metal. Time-to-cool from 1300 to 1100° F, 4.2 sec. Structure is ferrite, pearlite and carbide. 0.5% nital etch, X 500

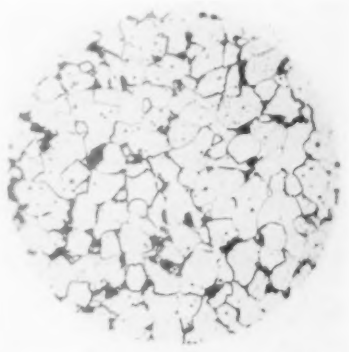

Fig. 4 Microstructure of Type 180 weld-metal pad. Structure is ferrite, pearlite and carbide. 0.5% nital etch, X 500

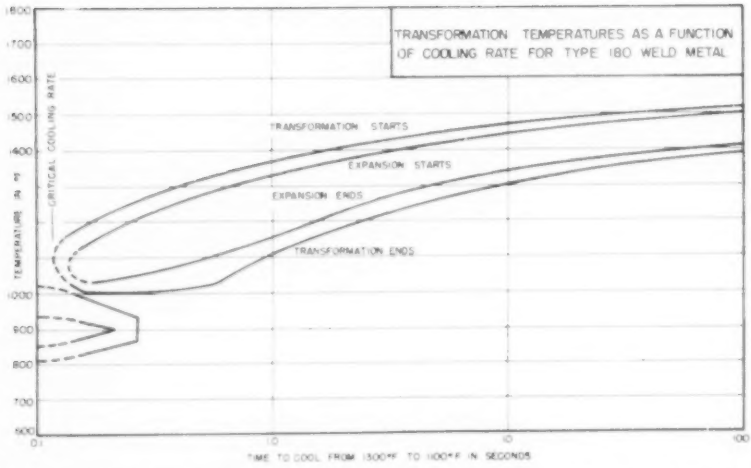
TRANSFORMATION TEMPERATURES AS A FUNCTION OF COOLING RATE FOR TYPE 180 WELD METAL
TRANSFORMATION STARTS
EXPANSION STARTS
EXPANSION ENDS
TRANSFORMATION ENDS
CRITICAL COOLING RATE
TEMPERATURE IN °F
TIME TO COOL FROM 1500°F TO 1100°F IN SECONDS

Fig. 5 Transformation diagram for Type 180 weld metal. Transformation temperature vs. cooling rate (time-to-cool from 1300 to 1100° F)

the completion of the pearlite reaction in those areas of the austenite which have been cooled just slower than their critical cooling rate.

The end of the "split" transformation range of cooling rates is passed when the cooling rate of the specimen becomes slower than the critical cooling rate of the most hardenable of the segregated regions. At all cooling rates slower than this, transformations occur entirely in the upper range of temperatures. The critical cooling rate of the most hardenable regions is considerably faster than any cooling rate which can reasonably be expected in an arc weld.

The constituents formed by the transformation of austenite at cooling rates slower than those in the "split" transformation zone are ferrite, pearlite and carbide. At low levels of carbon content, on the order of a few hundredths of a percent beyond the limit of solid solubility of carbon in ferrite, carbide is normally rejected from transforming austenite as discrete carbide particles, rather than as lamellae associated with similar ferrite lamellae in the form of pearlite. The nominal carbon content of this weld metal was somewhat high to exhibit this sort of structure, but, because of the segregated nature of the austenite, some areas of the austenite did transform to ferrite and carbide particles rather than to ferrite and pearlite. Other higher-carbon regions of the austenite formed pearlite on transformation. Consequently, the microstructures of slowly-cooled specimens show carbide present both as discrete carbide particles and as pearlite.

Figure 3 shows the structure of a dilatometer specimen which was cooled from 1300 to 1100° F in 4.2 sec. Although this is a comparatively-rapid cooling rate, the microstructure of the specimen is very similar to the microstructure of the bar of weld metal from which the specimens were machined, Fig. 4. These two microstructures, consisting of ferrite, pearlite and carbide, are typical of all the microstructures of specimens which were completely transformed in the upper range of transformation temperatures. There seemed to be a tendency for more free carbide and less pearlite to be formed as the cooling rate decreased, but similar evidence from a carefully-homogenized steel of the same general composition would be required before this behavior could be asserted to be a general rule.

Figure 5 shows the continuous cooling transformation data of Fig. 1 transposed in terms of time-to-cool from 1300 to 1100° F. It will be seen from this curve that the transformations of interest in arc welding will occur in the range from 1500 to 1400° F, corresponding to cooling times of 2 to 50 sec, i.e., average cooling rates of 100 to 4°F/sec at 1200° F.

Type 230 Weld Metal

The chemical analysis of the weld-metal pad was as follows:

%C	%Mn	%Si	%Ni	%Mo	%V
0.06	0.82	0.38	1.76	0.30	0.15

This composition corresponds closely to the composition claimed by the electrode manufacturer. It differs from the composition of Type 180 weld metal principally in the large amount of nickel and the presence of two strong carbide-forming elements, molybdenum and vanadium. The presence of these alloying elements can be expected to alter materially the continuous cooling transformation characteristics of this steel from those of a plain-carbon steel like Type 180 weld metal.

The specimens were austenitized at 1800° F for 2 min prior to quenching.

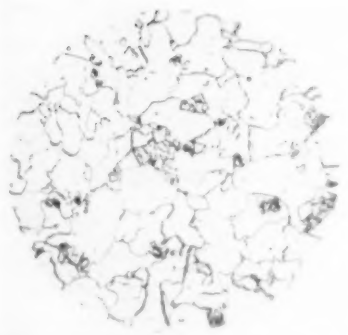

Fig. 6 Microstructure of dilatometer specimen of Type 230 weld metal. Time-to-cool from 1300 to 1100° F, 110 sec. Structure is ferrite and carbide. 0.5% nital etch, X 500

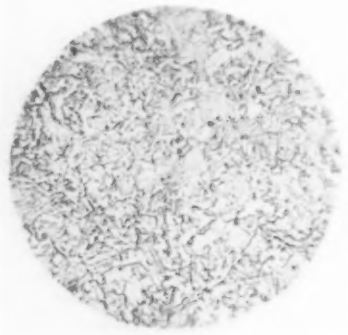

Fig. 7 Microstructure of dilatometer specimen of Type 230 weld metal. Time-to-cool from 1300 to 1100° F, 1.9 sec. Structure is ferrite, carbide and martensite. 0.5% nital etch, X 500

Fig. 8 Microstructure of Type 230 weld-metal pad. Structure is ferrite and carbide. 0.5% nital etch, X 500

The long austenitizing time as compared with Type 180 weld metal was necessary to remove the last traces of untransformed ferrite from the quenched structure. Patches of such ferrite were easily distinguishable in specimens which had been quenched at

rates near the critical cooling rate, and their disappearance from the structure was taken as the indication of complete austenitization.

The free carbides which appear in the microstructures of some of the slowly-cooled specimens show a spherical form which could be taken as an indication that the austenitizing treatment did not effect complete carbide solution. An incomplete solution of carbides during austenitization would not affect the critical cooling rate and the beginning of transformation, which are determined by the low-carbon, low-alloy regions of the segregated austenite, but would cause the temperature of the end of transformation to be too high.

An answer to the question of completeness of carbide solution was found in the microstructures of specimens which had been cooled at rates rapid enough to produce martensite. Free carbides were not visible in such specimens, which indicates that the round carbides present in the slowly-cooled specimens were the product of austenite transformation, rather than undissolved carbides. In addition to this evidence, Fig. 6 shows the structure of a very slowly-cooled specimen. This specimen was heated and cooled in a special electrical resistance-heated furnace which was designed to produce very slow cooling rates. The effective austenitization was greater in this furnace than in the induction coil, as shown by the coarser grains of Fig. 6 as compared with Figs. 7 and 8. Figure 6 shows the presence of free carbides as coalesced spheres, as compared with the slightly acicular carbides of Fig. 8. From these considerations it can be deduced that the austenitizing treatment effectively dissolved all of the carbide particles, and that the free carbide spheres present in the microstructures were formed as transformation products.

Figure 9, the continuous cooling transformation diagram for this weld metal, shows that transformations occur in three principal temperature regions. Martensite is formed in the range from 1025 to 640° F. The experimental Ms lies a little more than 100° F higher than the calculated Ms of 906° F. This is to be expected because the experimental Ms is determined by the composition of the low-carbon, low-alloy regions of the segregated austenite, while the calculation is made on the basis of a homogeneous austenite. The critical cooling rate was much slower than that of Type 180 weld metal because of the greater alloy content, and was well within the range of rapid cooling rates of the dilatometric equipment. The data of Fig. 9 are shown in Fig. 10 after replotting the transformation temperatures as

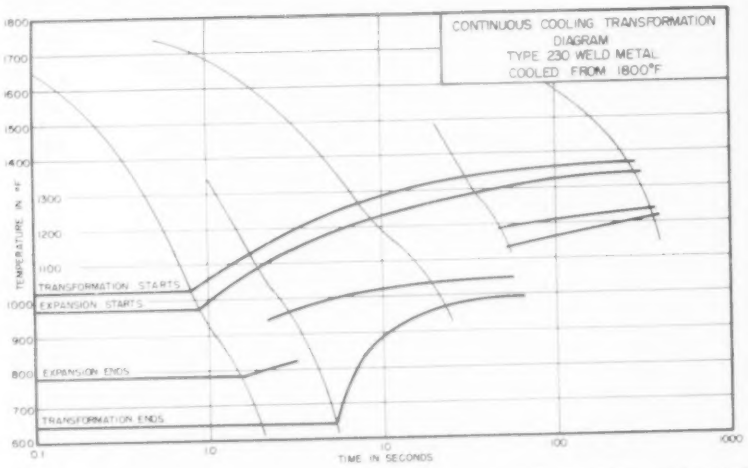

Fig. 9 Continuous cooling transformation diagram for Type 230 weld metal cooled from 1800° F

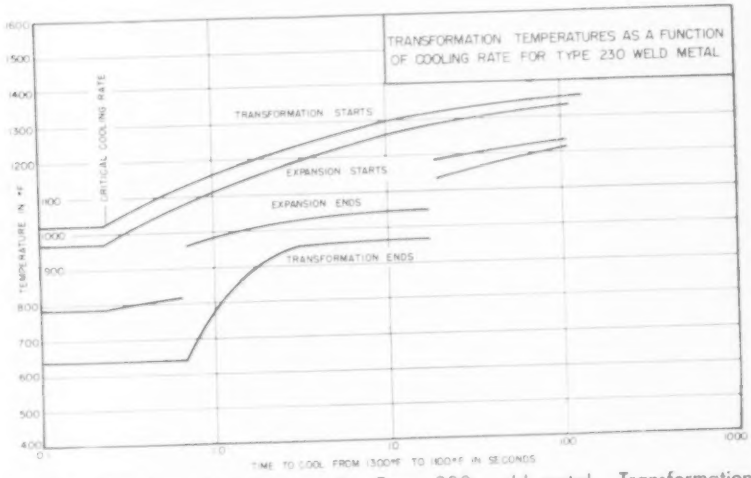
TRANSFORMATION TEMPERATURES AS A FUNCTION OF COOLING RATE FOR TYPE 230 WELD METAL
CRITICAL COOLING RATE
TRANSFORMATION STARTS
EXPANSION STARTS
EXPANSION ENDS
TRANSFORMATION ENDS
TEMPERATURE IN °F
TIME TO COOL FROM 1300°F TO 1100°F IN SECONDS

Fig. 10 Transformation diagram for Type 230 weld metal. Transformation temperature vs. cooling rate (time-to-cool from 1300 to 1100° F)

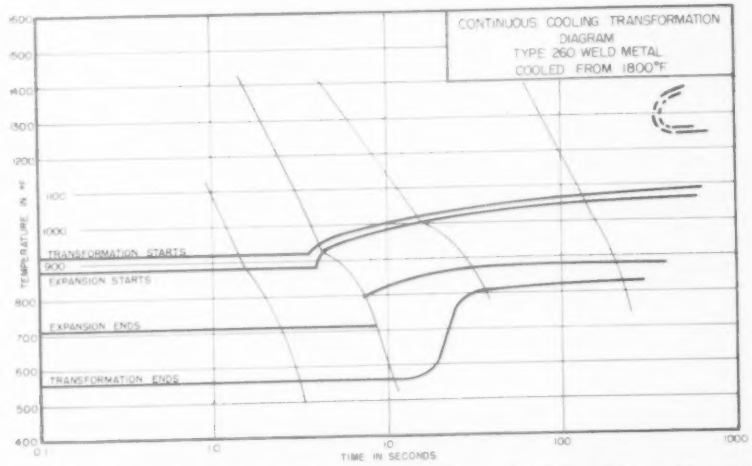

Fig. 11 Continuous cooling transformation diagram for Type 260 weld metal cooled from 1800° F

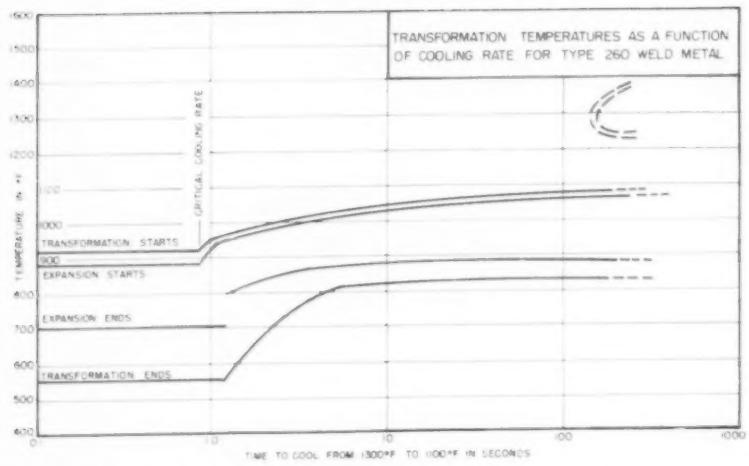
TRANSFORMATION TEMPERATURES AS A FUNCTION OF COOLING RATE FOR TYPE 260 WELD METAL
CRITICAL COOLING RATE
TRANSFORMATION STARTS
EXPANSION STARTS
EXPANSION ENDS
TRANSFORMATION ENDS
TEMPERATURE IN °F
TIME TO COOL FROM 1300°F TO 1100°F IN SECONDS

Fig. 12 Transformation diagram for Type 260 weld metal. Transformation temperature vs. cooling rate (time-to-cool from 1300 to 1100° F)

a function of the time-to-cool from 1300 to 1100° F.

The change in transformation temperatures as the cooling rate becomes slower than the critical cooling rate is a congruent transition, rather than the "split" transformation exhibited by the Type 180 weld metal. The first nonmartensitic transformation product is ferrite, formed in those low-alloy, low-carbon regions whose hardenability limits the hardenability of the structure as a whole. This ferrite is comparatively highly alloyed and precipitates at temperatures slightly higher than the Ms, rather than at much higher temperatures, as in the case of a "split" transformation. As the cooling rate becomes progressively slower than the critical cooling rate, small amounts of carbide appear. Figure 7 shows the structure of a specimen cooled slightly slower than the critical cooling rate. The structure consists of ferrite, carbide and martensite. The martensite areas indicate the scale of dendritic segregation in relation to the grain size. When the cooling rate of the specimen becomes less than the critical cooling rate of these areas, the temperature of the end of expansion rises abruptly, although some martensite is still being formed in the highest carbon regions.

At cooling rates slightly slower than the critical cooling rate of the most hardenable areas, a large portion of the transformation occurs in the temperature range which is usually identified with the formation of bainite. Examination of the microstructure did not disclose any structures which could be definitely classified as bainite. Figure 7 shows that the carbide particles within each ferrite grain are large and distinct, not submicroscopic and intimately associated with fine ferrite grains as in a true bainitic structure. However, the carbide particles within each ferrite grain appear to be in a roughly parallel alignment, as though they had precipitated along definite planes in the austenite crystal lattice. This structure may be considered to be a primitive form of bainite, characteristic of low-carbon, high-alloy steels.

At some comparatively-slow cooling rate there will be another congruent transition which marks the end of transformations below about 1150° F. The exact cooling rate at which this transition occurs is dependent on the austenitizing conditions used. The cooling rates at which the transition can take place lie within the range of cooling rates which are found in arc welding. At rapid weld cooling rates, therefore, weld-metal transformations can occur as low as 970° F. This temperature is within the range of some base-metal transformation temperatures, and may be even lower if the weld metal is alloy-enriched by fused metal from a high-alloy base plate.

Figure 8 shows the structure of a dilatometer specimen which was cooled slightly faster than the cooling rate required for the high-temperature congruent transition. The carbides are not as definitely oriented as in Fig. 7 and the slower cooling rate has allowed them to spheroidize slightly. They are, however, rather evenly distributed throughout the ferrite matrix, and the structure can be considered as belonging to the same class of transformation as the ferrite-carbide structure of Fig. 7.

At very-slow cooling rates, all of the transformation occurs at temperatures above 1160° F. The structure to be expected in this temperature region is ferrite, carbide and pearlite. Figure 6 shows the structure of a dilatometer specimen which took 110 sec to cool from 1300 to 1100° F. There are many small spheroids of free carbide in the ferrite matrix. Larger particles of carbide are agglomerated into groups which resemble a rudimentary pearlite. It would appear that, under the alloying conditions in this steel, carbides tend to precipitate as discrete particles rather than form laminations with ferrite.

Type 260 Weld Metal

The chemical analysis of the weld-metal pad was as follows:

%C	%Mn	%Si	%Ni	%Mo	%V
0.07	1.00	0.40	1.80	0.82	0.27

This composition corresponds closely to the composition claimed by the electrode manufacturer and differs from the Type 230 composition principally in that it contains approximately 0.50% more molybdenum and 0.10% more vanadium.

A continuous cooling transformation diagram for this grade of weld metal has been published by Bailey and Harris.[2] There are a number of points of difference between their curve and the continuous cooling transformation diagram of this investigation, Fig. 11. These differences will be specifically noted as a part of the discussion of Fig. 11.

The specimens were austenitized at 1800° F for 4 min prior to quenching. The long austenitizing time was required to dissolve alloy carbides. A certain amount of homogenization was unavoidable during this treatment but it was believed that less complete carbide solution would give a distorted impression of the transformation characteristics.

Figure 11 and Figure 12, the curve for transformation temperatures as a function of time-to-cool from 1300 to 1100° F, show that the high-alloy content imparts a considerable hardenability to this steel in spite of the very-low carbon content. The Ms is 70° F higher than that reported by Bailey and Harris,[2] which is to be expected in view of the fact that their material was homogenized at 2000° F for 20 min while this investigation sought to establish the behavior of as-deposited weld metal.

A comparison of Fig. 11 of this report and Fig. 6 of Bailey and Harris[2] discloses a significantly slower critical cooling rate in the former. Decarburization or an initial lack of homogeneity are the primary causes of such a discrepancy in high-speed dilatometer measurements. Both sources of trouble would lead to an abnormally-high Ms. It is difficult to account for both the lower hardenability and the lower Ms in the data of Bailey and Harris. These authors do not definitely state whether their Ms value

is measured or calculated from chemical composition, although the general tenor of their discussion suggests that it was determined experimentally. However, their Ms value of 850° F is so close to the calculated value as to indicate that it was determined in this way. Their report does not include any photomicrographs of the structures of continuously-cooled specimens for comparison with those included in this report. However, some of their photomicrographs of isothermally-transformed structures suggest that severe segregation persisted in spite of their homogenizing treatment.

Figure 11 shows a congruent transition to nonmartensitic transformation products as the cooling rate becomes slower than the critical cooling rate of the least hardenable regions of the structure. The general form of this portion of the curve is similar to the corresponding region of the curve for Type 230 weld metal. As the cooling rate decreases, the temperature of the beginning of transformation rises gradually, but at a slower rate than in the case of the Type 230 composition, and never reaching as high as 1100° F. The end of transformation in this range of cooling rates reaches a maximum temperature of 830° F.

The structure formed in this range of transformation temperatures consists of ferrite and carbide. A typical microstructure is shown in Fig. 13. The range of cooling rates which produces this type of structure corresponds to the range of cooling rates encountered in a weld. Consequently, Fig. 13 is identical in microstructural characteristics to Fig. 14, a photomicrograph of the structure of the Type 260 weld-metal pad. The carbide is associated with the ferrite in what appears to be a primitive form of bainite; better developed than the corresponding structure encountered in the same temperature range in Type 230 weld metal, but still not the typical finely-dispersed, rapid-etching structure of the classical bainite. None of the continuously-cooled structures resembled the structure obtained isothermally between 900 and 1100° F as shown in Fig. 5 of Ref. 2.

Bailey and Harris show the beginning of transformation in this temperature range as a horizontal line at a constant temperature of about 1060° F. This horizontal line implies that the transformation temperature is independent of cooling rate over a very wide range of cooling rates. Such behavior is not typical of sub-critical nucleation and growth reactions in general, and is not to be expected from Fig. 4 of Ref. 2, in which the corresponding line on the isothermal transformation diagram shows a slight, but definite slope.

Fig. 13 Microstructure of dilatometer specimen of Type 260 weld metal. Time-to-cool from 1300 to 1100° F, 16 sec. Ferrite-carbide structure, 0.5% nital etch, X 500

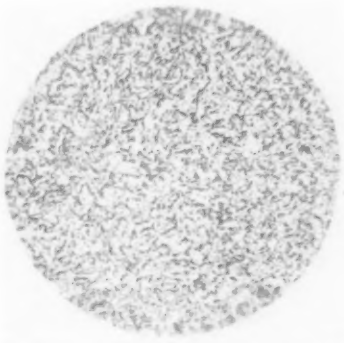

Fig. 14 Microstructure of Type 260 weld-metal pad. Structure is of same type as that of Fig. 13. 0.5% nital etch, X 500

Fig. 15 Microstructure of dilatometer specimen of Type 260 weld metal. Time-to-cool from 1300 to 1100° F, 180 sec. Ferrite grains which are free from acicular carbides were formed in the upper range of transformation temperatures. 0.5% nital etch, X 500

No transformations were encountered at temperatures above 1100° F over the entire range of cooling rates which would be expected in arc welding. Even at a time to cool from 1300 to 1100° F of 125 sec, the first transformation product appeared at a temperature of 1070° F. This cooling rate was achieved by replacing the plain stainless-steel heating pipe of the dilatometer by one wrapped with resistance alloy wire to form an electrically-heated furnace. After austenitization, the current through the furnace winding was slowly decreased, providing continuous cooling at a very slow cooling rate. Since it is metallurgically obvious that this diagram must contain a range of transformation temperatures higher than 1100° F, an attempt was made to locate this transformation range for the sake of completing the diagram, in spite of the fact that the range of cooling rates which would produce such a transformation would not be encountered in a practical weld. With the very slow cooling of a few specimens in the resistance furnace tube, an upper range of transformation was encountered at a time-to-cool from 1300 to 1100° F of 180 sec, as a portion of a "split" transformation. The temperature of this transformation is indicated on the diagrams as an incomplete curve. The "nose" of this curve lies at some point to the left of the transformation time for this one specimen and is indicated on the diagram by a dotted line which signifies that the line is schematic, not based on complete data. The time and temperature of this beginning of the upper temperature range of transformation would be very strongly influenced by austenitizing conditions, and would be of real significance only in the case of a transformation diagram based on homogeneous specimens.

The structure of the specimen exhibiting the upper transformation temperature range is shown in Fig. 15. In this structure a few scattered patches of ferrite appear amid a ferrite-carbide structure identical to that of Fig. 13, and obviously formed in the lower temperature range of transformation. A few spheroidal particles of carbide may be seen in the grains of free ferrite. The carbide particles in the ferrite-carbide structure show a tendency towards spheroidization. At much slower cooling rates the lower temperature region of transformation can be expected to disappear and the austenite to transform entirely at temperatures above 1200° F. The structure would then resemble that of Fig. 6 for Type 230 weld metal.

It is in the location of this upper range of transformation that the data of Fig. 11 is in most serious disagreement with that of Bailey and Harris.

Their diagram shows the upper temperature range of transformation products as occurring at comparatively-rapid cooling rates, well within the range of cooling rates encountered in welding. Examination of Type 260 weld metal deposited under conditions designed to produce very-slow cooling rates (13° F/sec) did not reveal the characteristic free ferrite patches of Fig. 15, indicating that the "nose" of the upper transformation limit curve must lie to the right of its location in the diagram of Bailey and Harris. Another factor which would indicate that this should be the case, is the location of the "nose" of the isothermal diagram, Fig. 4 of Reference 2. A comparison of Fig. 4, the isothermal diagram, with Fig. 6, the continuous cooling diagram, shows the "nose" occurs at exactly the same temperature and at approximately the same time in both diagrams. It is normally expected that the "nose" of an isothermal transformation diagram is shifted to lower temperatures and longer times under conditions of continuous-cooling transformation. Although the present experimental investigation did not locate the ferrite curve exactly, the small amount of free ferrite shown in the structure of Fig. 15 indicates that the position of the ferrite "nose" in Fig. 14 (and Fig. 12) is essentially correct.

Summary of Weld-Metal Characteristics

The data concerning the transformation characteristics of these three types of weld metal permit some conclusions to be drawn concerning the effects of alloy additions to welding electrodes.

The alloys in weld metals can improve mechanical properties by means of two mechanisms: solid-solution strengthening and the alteration of carbide spacing. Increasing the hardenability is, in effect, an alteration of carbide spacing because martensite formation is not intended.

The alteration of the plain-carbon type of weld metal, as exemplified by the Type 180 composition, by the addition of large amounts of nickel increases the mechanical properties of the steel principally through the strengthening and toughening effect of nickel in solid solution in the ferrite. The carbide spacing is also decreased to some extent by the effect of nickel on the hardenability. The extent to which mechanical properties can be increased by the solid-solution strengthening mechanism is limited, and does not compare with the increase in properties obtained by alloying for hardenability in heat-treatable steels. It is also an uneconomical method, particularly in the case of strategic metals such as nickel. The use of nickel in weld-metal compositions is feasible because of the requirement of increasing the strength without a consequent decrease in ductility and toughness.

The addition of carbide-forming elements, such as molybdenum and vanadium, to weld-metal compositions improves the mechanical properties of the deposited metal through two different mechanisms which have the same result, an alteration of the spacing of carbide particles. It was noted during the comparison of the slow-cooled structures of Type 180 and Type 230 weld metal that in the latter case the carbide particles did not form a true pearlitic structure. This finer spacing between carbide particles decreases the mean free path through the ferrite and hence increases the strength of the metal.

An even more effective means by which the inclusion of carbide-forming elements decreases the mean free path through the ferrite occurs through the effect of this class of elements on the transformation characteristics of the weld metal. A comparison of the continuous cooling transformation diagrams of the three types of weld metals shows this effect graphically. There is no bainitic transformation in the Type 180 weld metal and the transformation diagram shows a "split" transition from martensitic to non-martensitic transformation temperature regions. In the Type 230 composition, the alloying additions cause a portion of the transformation to occur in the bainite-forming temperature range. The resultant structure, although it might not be called a true bainite, consists of small, well dispersed carbide particles in a ferrite matrix. The size and dispersion of these carbide particles radically reduce the mean free path through the ferrite with a consequent increase in the strength of the metal. The addition of further vanadium and molybdenum to produce Type 260 weld metal causes this structure to be formed over a wide range of cooling rates with an even shorter mean free-ferrite path.

The use of alloying elements to increase mechanical properties by causing austenite to transform at comparatively-low temperatures is sound metallurgical practice as far as the weld metal itself is concerned. However, when the weld-metal transformations are viewed in conjunction with the base-metal transformations, some unfortunate consequences may arise.

When the transformation temperature ranges of the weld metal and the base metal overlap, the two can transform simultaneously after welding. This situation can lead to severe stresses which can cause cracking or can leave residual stresses which will impair the mechanical properties of the weld. Another possible source of trouble can be seen from a comparison of the transformation temperatures and the structures formed in an alloy base metal and Type 260 weld metal. In this case, a martensitic heat-affected zone is required. However, the weld metal does not complete its transformation until almost the Ms temperature of the base metal, and the structure formed in the weld metal closely resembles the bainitic structure formed in the base metal at cooling rates slower than its critical cooling rate. It is possible that certain favorably-oriented grains of transforming weld metal could nucleate a bainitic transformation in correspondingly oriented grains of base metal adjacent to them across the fusion line, at cooling rates faster than the critical cooling rate of the base metal. Such an interaction between weld metal and base metal would cause unsatisfactory weld structures to be produced under perfectly designed welding conditions.

Acknowledgment

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FATIGUE STRENGTH OF SILVER-ALLOY BRAZED JOINTS IN STEEL

Laboratory investigation leads to quantitative information regarding the fatigue strength of butt joints in steel brazed with B-Ag-1 alloy

BY C. H. CHATFIELD AND SAM TOUR

Introduction

Brazed joints are regularly used where they are subject to fatigue; in fact, one of the first major uses of silver brazing was in the refrigeration industry where soft solders were discarded in favor of the silver-brazing alloys on account of the improved resistance to fatigue under vibration of silver-brazed joints. Despite the importance of the fatigue endurance of brazed joints the literature on the subject is meager. With the exception of a brief mention by Coxe and Setapen[1] on the fatigue strength of silver-brazed silicon-bronze joints and by Brooker and Beatson[2] on joints made on brass and mild steel, there is little published information.

The fatigue strength of a material is generally proportional to the tensile strength. It has been shown [3, 4] that the tensile strength of sound butt joints is determined by the strength and hardness of the base metal brazed and by the thickness of the joint. The purpose of this investigation was to obtain quantitative information regarding the effect of these factors in fatigue. It is recognized that the standard specimen used for fatigue testing on an R. R. Moore rotating-beam machine is a poor design for practical applications, and that the figures obtained are not directly applicable by the designer of an assembly to be used in fatigue. In practice, it is usually possible to design so that the joint does not coincide with the point of maximum stress.

Two steels were selected for the tests: SAE 1020 steel having a tensile strength before brazing of 64,000 psi, and SAE 4140 steel heat treated to a tensile strength of 164,000 psi before brazing. This range of strength should be sufficient to determine whether or not the strength of the base metal materially influenced the fatigue strength of the joints. With each steel, two series of joints were made: one having a nominal thickness of joint of 0.010 in. and the other having a nominal thickness of joint of 0.001 in. The purpose of this was to determine whether the fatigue strength of a joint was affected by the thickness of the joint in the same manner as is the tensile strength.

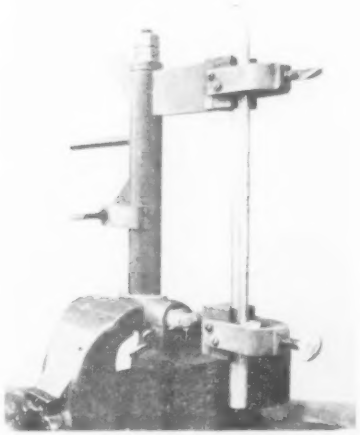

Fig. 1 Jig for holding specimens in alignment and properly spaced to give desired joint thickness

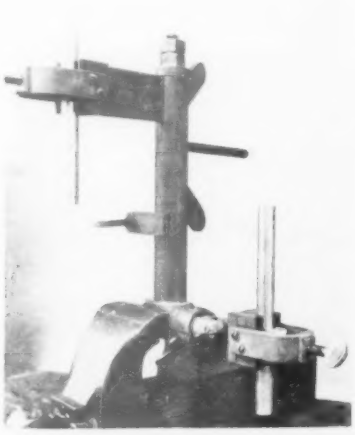

Fig. 2 Same as Fig. 1 but in open position for pretinning ends of specimen with brazing alloy

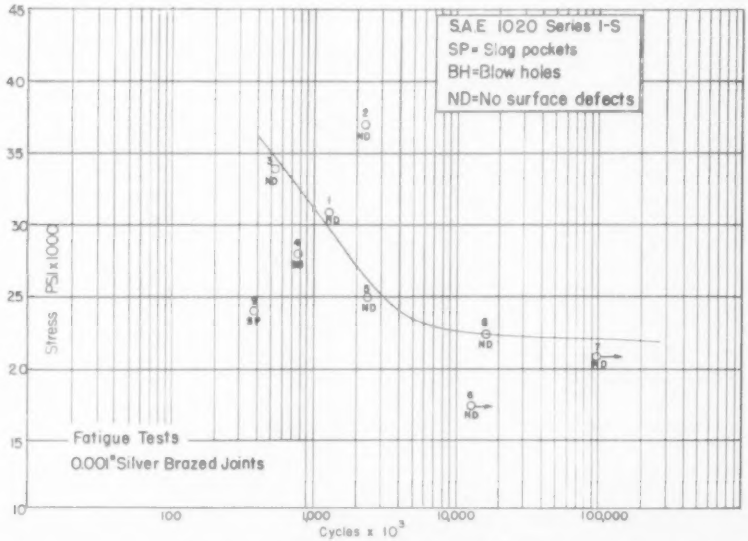

Fig. 3 Fatigue tests on SAE 1020 steel with silver-brazed joints 0.001 in. thick

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Paper presented at the AWS National Spring Meeting, 1956, May 7–11, Buffalo, N. Y.

Procedure

The joints for the tests were torch brazed using an oxyacetylene torch for heating. Two pieces of rod 4 in. long x ½ in. diam were butt brazed with a silver-brazing alloy conforming to the AWS A5.8 52T specification BAg-1.

The specimens for brazing were mounted vertically on two horizontal arms attached to a center post (see Figs. 1 and 2). The gap between the butt ends of the specimens could be adjusted by set screws so that at the brazing temperature the desired thickness of joint could be obtained. In addition, the top arm could be swung sideways in order to give a wiping motion to the joint while the brazing alloy was molten and thus eliminate most of the flux inclusions. The joint was made by first tinning the ends of the rods to be joined with the brazing alloy and then, while the brazing alloy was molten, swinging the upper half of the joint into alignment with the lower half of the joint. As soon as the brazing alloy solidified, the upper half of the joint was released from the holder thus allowing the joint to contract freely during cooling without any constraint from the jig. This procedure has been found to give joints which are relatively consistent in tensile properties.

After brazing, code numbers were assigned the specimens as follows:

The 1020 steel was identified by the numeral "1"; the 4140 steel by the numeral "4"; the 0.001-in. thick brazed joints by the letter "S" (for short); the 0.010-in. thick brazed joints by the letter "L" (for long). The bars were then numbered from 1 through 12. Thus the first bar was marked 1S1, the second 1S2, the third 1S3 and so forth.

Nine bars of each group were machined and ground into standard R. R. Moore rotating-beam fatigue-test specimens with a centrally located 3½-in. radius. Fatigue tests were run on an R. R. Moore machine.

Two bars from each group were machined and ground into tensile test specimens with gage-length diameter of the same size as the rotating-beam specimens. Tensile tests were made on these specimens (see Table 3).

The first three bars of each group were also examined by X-ray radiography.

Results

For maximum clarity in radiography, the bars were immersed in concentrated lead-acetate solution and X-rayed with a source-to-film distance of 33 in. at 150 kvp–6ma, first with a 9-min exposure and then again with a 20-min exposure. In both cases, the brazing-alloy planes showed clearly, but it was not possible to find evidence of porosity in the brazing alloy due to inadequate penetration of the X-rays through the silver-alloy layer and scatter radiation from the surface. The tests indicated, only, that any porosity in the joint was finer than the limit of sensitivity which

Table 1—Fatigue Tests

Bar no.	*Joint thickness, in.*	*Porosity-surface*	*Stress, psi*	*Cycles × 1000*	*Remarks*
1S1	0.002	None noted	31,000	1,252	
2	0.001	None noted	36,900	2,222	
3	0.001	None noted	34,300	520	
4	0.001	None noted	28,000	782	
5	0.001	None noted	25,000	2,397	
6	0.001	None noted	17,500	13,164	No failure
7	0.001	None noted	21,000	100,182	No failure
8	Below 0.001	None noted	22,500	16,533	
9	0.001	Slag pockets	24,000	397	
1L1	0.008	None noted	17,500	12,002	No failure
2	0.008	None noted	38,000	119	
3	0.010	Minor	34,000	109	
4	0.011	One about 0.007 in.	26,000	170	
5	0.011	Minor	22,000	541	
6	0.014	Major	19,000	2,066	
7	0.010	One blowhole 0.008 in.	19,500	56,540	
8	0.012	One blowhole 0.012 in.	29,000	619	
9	0.010	None noted	27,000	560	
1S1	0.001	None noted	40,000	1,201	
2	0.001	None noted	15,000	43	
3	0.002	None noted	27,000	1,959	
4	0.001	None noted	23,000	9,324	
5	0.001	None noted	34,000	1,835	
6	0.002	None noted	22,000	100,374	No failure
7	0.001	None noted	31,000	1,973	
8	0.001–0.003	Slag pocket 0.002–0.006	37,000	44	
9	0.001	None noted	38,000	394	
1L1	0.010	Major, two 0.008 in.	35,000	32	
2	0.011	Major, two 0.010 in.	30,000	737	
3	0.010	Major, one 0.007 in.	32,500	109	
4	0.019	Minor	28,000	97	
5	0.013	None noted	24,500	100,459	No failure
6	0.012	Major, one 0.008 in. one 0.005 in.	24,500	2,667	
7	0.011–0.014	Four blowholes	25,500	590	
8	0.013	None noted	26,500	809	
9	0.012–0.015	One blowhole 0.007 in.	30,000	142	

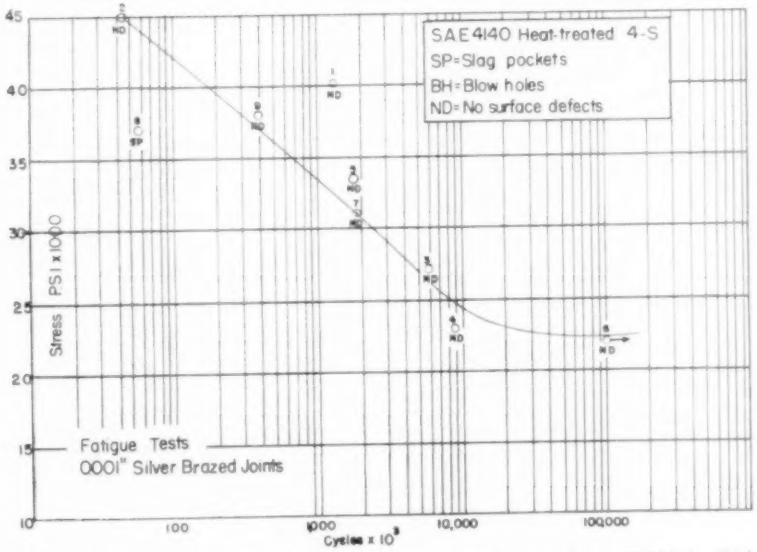

Fig. 4 Fatigue tests on SAE 4140 steel with silver-brazed joints 0.001 in. thick

Table 2—Fracture Faces

1S1—Evidence of porosity on one side and nonuniformity of solder thickness.
1S2—Minor porosity in one area, uniform solder, a bit of parent metal included in break on one face.
1S3—Uniform solder, scattered porosity, coarse on one side.
1S4—Medium porosity, large scattered voids 0.008 to 0.012 diam.
1S5—Medium porosity, failure face clean and smooth.
1S6—No failure.
1S7—No failure.
1S8—Scattered gas holes 0.007 to 0.010 in.
1S9—Minor porosity—five slag pockets 0.035 to 0.050 in. on half of joint.
1L1—No failure.
1L2—Major blowholes in center of break, several large on one side.
1L3—One large blowhole, approximately 0.070 in. midway between center and outside, scattered porosity elsewhere.
1L4—Two blowholes near edge approximately 0.040 in., major porosity in remainder.
1L5—One blowhole approximately 0.060 in. midway center to periphery, medium porosity remainder.
1L6—Scattered blowholes averaging 0.020 in. diam.
1L7—Blowholes 0.005 to 0.025 in.—scattered.
1L8—Numerous blowholes and voids 0.010 to 0.060 in. diam.
1L9—Scattered voids 0.050 to 0.060 in.—ragged fracture.
4S1—Clean, uniform; scattered minor porosity.
4S2—Medium porosity over half of fracture; uniform solder thickness.
4S3—Minor porosity, in general; medium porosity on 25% of fracture face on one side.
4S4—Medium porosity covering 40% of fracture face on one side.
4S5—Minor porosity.
4S6—No failure.
4S7—Scattered minor porosity—several small blowholes near one edge 0.020 to 0.025 in. diam.
4S8—Profusion of small voids—from 0.010 in. near one edge and decreasing in size to 0.001 on opposite edge.
4S9—Scattered minor porosity—0.010 to 0.020 in. diam. Area of dissimilar color 0.050 x 0.080 in. one edge.
4L1—Major porosity, two large blowholes approximately 0.040 in. diam. near edge.
4L2—Major blowholes, approximately 0.025 in., quite numerous on entire face.
4L3—Minor porosity, one blowhole approximately 0.025 in. near edge.
4L4—Fracture face well covered with major porosity—blowholes approximately 0.025 in.
4L5—No failure.
4L6—Large blowholes approximately 0.025 in. scattered over fracture face.
4L7—Scattered blowholes 0.005 to 0.020 in.
4L8—Numerous voids 0.008 to 0.010 in.
4L9—Six blowholes 0.010 to 0.025 in. on one half; several blowholes 0.005 in. diam on edge where fracture appears to have originated.

the X-rays could detect.

After machining and finishing the test bars, the thicknesses of the brazing-alloy layers were measured to the nearest 0.001 in. with a shop microscope. The results are shown in Table 1. The joint thicknesses for the 1S and 4S groups were consistent and did not vary more than 0.001 in. In the 1L and 4L groups variations in joint thickness varied from 0.002 in. low to 0.009 in. high. The tendency towards large variations in thickness of the 0.010-in. joint was greater in the 4140 steel than in the 1020 steel. Variations in thickness of the joints was caused by temperature variations during brazing as the temperature could not be closely controlled in torch heating. The gap between the ends of the joint varied as the expansion of the test pieces changed with the brazing temperature.

The outside surfaces of the specimens were examined for joint porosity and the results are shown in Table 1. It will be noted that, of the 18 bars machined from the samples of 0.001-in. thick joints, only two showed signs of any blowholes or slag pockets. On the other hand, of the 18 bars machined from samples with the 0.010-in. thick joints, only five were free from surface defects. Also the defects were larger and more prevalent on the bars of 4140 steel than on the bars of 1020 steel. These differences are in line with the general experience in silver brazing that thinner joints, within limits, tend to be sounder and stronger than joints having large clearances.

Fatigue tests were run at the stresses and for the number of cycles shown in Table 1. The fractured faces of the fatigue specimens that failed were examined and the occurrence of porosity noted and recorded in Table 2. The results of the tests are charted in Figs. 3 to 6, inclusive.

The tensile tests of the thin brazed joints of the 4140 steel show considerable variation. This is probably the result of differences in hardness after the brazing, as the brazing operation reduced the Rockwell hardness at the braze from C34 to about C25-27. Hardness variations in the thin joints would affect the tensile strength more than in the thick joints.

Discussion of Results

The controlling factor in the fatigue strength of silver-brazed joints appears to be the soundness of the joints rather than either the strength of the base metals or the thickness of the

Table 3—Tensile Tests

No.	Joint thickness, in.	Appearance	Diameter, in.	Yield strength, × 1000, psi	Ultimate strength, × 1000, psi	Elongation 1 in. = %	Location of break	Description of fracture
1S10	0.001	No defects	0.292	46.3	65.0	34.0	Outside braze	Necked down 1/8 in. from braze
1S11	0.001	No defects	0.297	44.4	67.2	27.0	In braze	Some necking of steel. Fine to medium porosity in braze
1L10	0.011	Three blowholes 0.003, 0.007, 0.017 in.	0.301	50.4	57.3	3.0	In braze	Three large blowholes 0.040 in. Coarse porosity
1L11	0.010	Five blowholes each 0.005 in.	0.300	51.5	67.8	12.0	In braze	Scattered blowholes 0.015 to 0.025 in.
4S10	0.002	Four blowholes 0.005 to 0.008 in.	0.300	...	113.3	0	In braze	Fine porosity. Several pockets 0.020 in. on one side
4S11	0.001	Four blowholes 0.003 to 0.006 in.	0.299	...	79.9	0	In braze	Fine porosity. Several pockets 0.020 in.
4L10	0.012	Four blowholes 0.005 in.	0.299	...	77.0	1.0	In braze	Four blowholes 0.030 to 0.040 in. One blowhole 0.015 in.
4L11	0.015	Six blowholes 0.005 in. One 0.015 in.	0.294	...	67.1	1.0	In braze	Numerous blowholes 0.005 to 0.025 in. Coarse structure

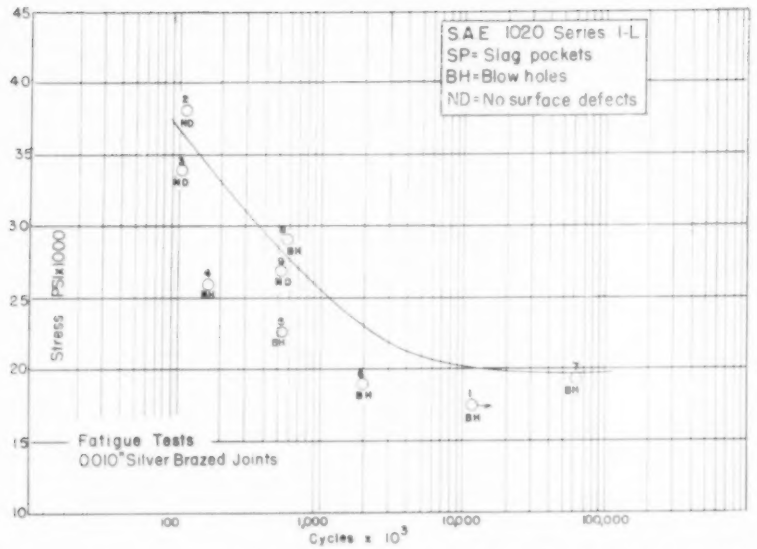

Fig. 5 Fatigue tests on SAE 1020 steel with silver-brazed joints 0.010 in. thick

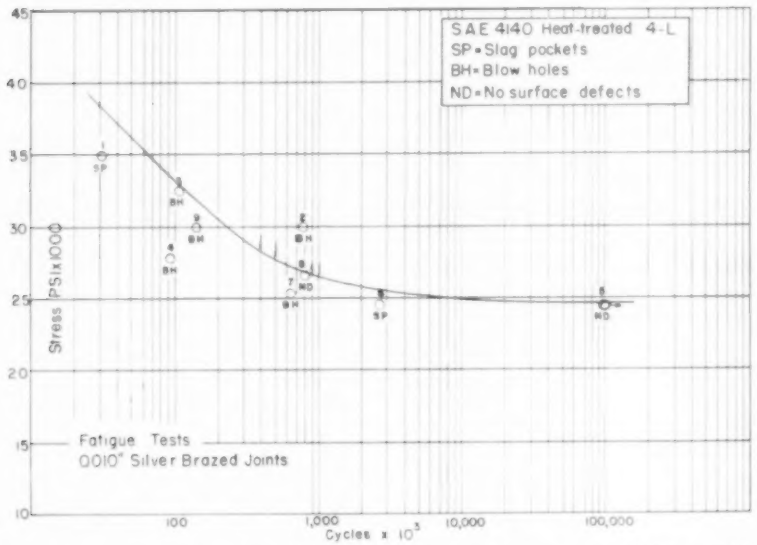

Fig. 6 Fatigue tests on SAE 4140 steel with silver-brazed joints 0.010 in. thick

joint. As would be expected, imperfections at the surface of the joint are much more harmful than imperfections which are well within the joints; the surface imperfections tend to give a notch effect.

The fatigue strength of the 0.001-in. thick joints, reasonably free of voids and slag inclusions, is of the order of 22,500 psi at 100 million cycles for both the 1020 and 4140 steels indicating that there is little or no relationship between the tensile strength and fatigue strength of silver-brazed joints. It is probable that, in butt joints such as these, the silver-brazing alloy, having a much lower modulus of elasticity than the steels, acts much the same as a notch in that the stress would be concentrated at this point and would limit the fatigue strength irrespective of the tensile strength of the joint.

The fatigue strength of the 0.010-in. joints in 4140 steel is somewhat higher (24,500 psi) than in the 1020 steel (19,500 psi). The number of tests run was too few to determine whether this is a significant difference, as the particular 1020 steel specimens tested in this stress range appeared to be less sound than the 4140 steel joints. Any gain in fatigue strength which might be obtained from a wide joint as against a thin joint, much as the shape of a notch may affect the strength of a joint, would be more than offset by the greater difficulty of obtaining a sound thick joint than a sound thin joint.

Conclusion

To summarize, the fatigue strength of butt joints in steel brazed with B-Ag-1 is of the order of 22,500 psi, irrespective of the strength of the steel. The thickness of the joint, within the limits of clearances normally used in silver brazing, does not materially affect the results. These conclusions are valid only for joints reasonably free from surface defects, as such defects may play a major role in the fatigue resistance of silver-brazed joints.

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DISCUSSION BY KARL M. WEIGERT

The authors have chosen a subject of great practical interest, and we hope that this is only the beginning of a series of tests.

From the large variety of commercial brazing alloys (K. Weigert, Electrical Manufacturing, September 1954, pages 143-146) only the 45% silver solder was mentioned which is recommended only for very tight joints (0.002-0.004 in.). For wider clearances and applications where brazed joints are subjected to shock and vibration, cadmium-free nickel-bearing compositions have been found to be superior. A quantitative comparison of fatigue properties of various commercial silver solders would be worth while to investigate.

Karl M. Weigert is Research Metallurgist with Curtiss-Wright Corp., Research Division, Quehanna, Pa.

AUTHORS' CLOSURE

We wish to thank Mr. Weigert for his remarks and we agree that the comparison of the fatigue strength of various solders would be valuable. However, no further tests are contemplated at present.

Plant, Research Laboratories and World Headquarters

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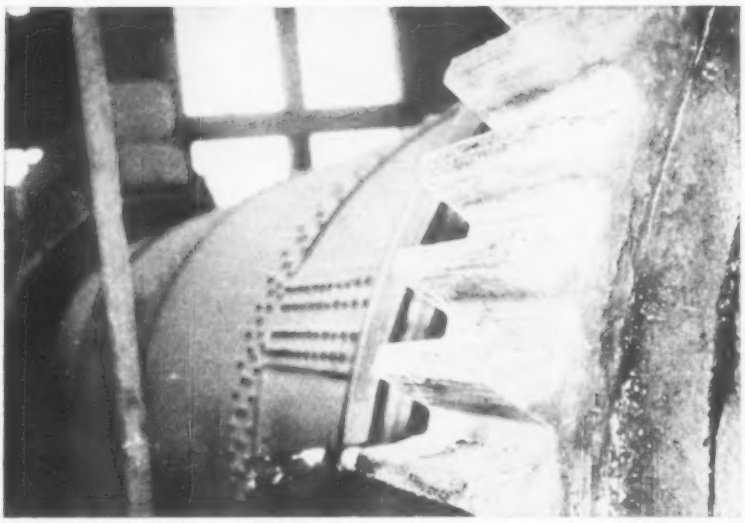

(Each tooth required 2½ pounds of alloy for overlaying; each is a foot long. Job was further complicated by sticky coat of grease over the entire gear.)

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